元分析论文自检报告

请作者填写以下内容, 粘贴在稿件文档的首页。

1. 请叙述本元分析的必要性和理论贡献（如果仅是单纯的量化来整合以往的研究效应，并基于此考察可能的调节变量，却无实质性的理论贡献，本刊不予接受）。

答：

必要性：首先，与物质成瘾相比，行为成瘾作为一种新型的成瘾类型，其影响范围更广，更具有普遍性。如，第 5 次全国未成年人互联网使用情况调查报告指出，我国玩电脑游戏的未成年网民比例为 24.0%，而玩手机游戏的未成年网民比例高达 62.8%。且进一步研究发现，行为成瘾和物质成瘾类似，均会损伤个体抑制、注意和奖赏等能力。在成瘾过程中，神经机制发生大规模变化，而正是这种变化影响使认知功能表现出异常。因此，有必要综合分析不同任务模式下行为成瘾神经机制变化。**其次，**相对于物质成瘾，由于行为成瘾个体未摄取药物就导致了腹侧纹状体参与强迫性感觉寻求和受损的奖励回路激活，前额叶参与不可阻挡的控制行为等物质成瘾共性问题。行为成瘾排除了药物的混合影响，为研究成瘾的神经机制提供了一个理想的模型；而这个模型反过来又促进了物质成瘾研究，为物质成瘾剥离药物影响提供一种现象学视角。因此，探究物质和行为成瘾两种不同成瘾行为相似和差异性神经机制，也能为更深刻理解物质和行为成瘾也提供新视角。

理论贡献：1、目前关于行为成瘾的理论解释多数来源于对物质成瘾理论的借鉴。如激励敏化理论(强调在成瘾过程中，多巴胺系统对成瘾刺激物的敏化，导致成瘾被试对成瘾刺激物及其相关线索的敏感性增加)、双系统理论(强调以前额叶为主的反思系统和以纹状体为主的冲动系统之间的相互竞争对成瘾的影响)。虽然，这些理论能很好的解释行为成瘾相关行为，但是物质成瘾是通过药物直接对神经系统产生影响；而行为成瘾更多是基于认知角度。**因此，基于双系统理论视角，行为成瘾与物质成瘾在多大程度上存在一致性激活、在多大程度上存在分离需要进一步研究进行明确。**而本研究通过检索物质成瘾和行为成瘾相关磁共振任务，系统地比较物质成瘾和行为成瘾神经机制相似性和特异性。2、根据 Brand(2022)提出的行为成瘾过程的神经模型，行为成瘾分为前期的 feel better 和后期的 must do 两个阶段，每个阶段存在不同的神经环路。**因此，本研究通过收集行为成瘾在不同磁共振任务中的神经激活，从而检验行为成瘾是否如同 Brand(2022)提出的神经模型，存在 must do 环路变化**。

2. 本元分析的文献检索及数据编码过程是否完备？（包括文献纳入的标准，用什么关键词及检索式检索了哪些数据库，文献的年代范围，检索时间，文献纳入及排除标准，如何选

择结果变量、调节变量，如何保证编码质量，最后共有多少条文献纳入）
答：

目前元分析研究所有过程都符合规范，并留有记录。

文献纳入标准及其排除标准：

目前研究的目的是比较物质和行为成瘾任务态下神经机制相似性和特异性变化。因此，设置如下文章**纳入标准**：1、必须是物质或行为成瘾文章；2、文章必须是基于任务态的功能磁共振成像(fMRI)研究；3、实验获得的脑区必须是物质或行为成瘾被试同健康对照组相比较获得的；4、采用全脑(whole-brain)分析得出结果。

排除标准：1、非磁共振文章；2、不是物质成瘾或行为成瘾被试的文章；3、非人类研究不予与采纳；4、药物治疗研究不予与采纳；5、文献需为实证研究，综述、元分析及个案研究不予与采纳；6、文章需要经过同行评审并发表，硕士和博士论文不予与采纳；7、未达到 DSM 或者成瘾问卷标准的文章不予与采纳；8、存在结果但未在文中标注出来。

关键词、数据库、检索时间：

目前研究采用的**关键词**来源于综合了先前已经发表的相似主题的元分析文章和做过相似主题元分析研究者的建议。参考过的文献有：Qiu 和 Wang(2021)、Le 等人(2021)、Hüpen 等人(2023)、Klugah-Brown 等人(2021)、Tolomeo 和 Yu(2022)、Yao 等人(2017)、Poudel 等人(2020)、Luijten 等人(2017)、Zeng 等人(2023)这九篇文章。具体关键词如下："neuroimaging"、"functional MRI"、"fMRI"、"functional Magnetic Resonance Imaging"和"addiction"、"substance use disorder"、"substance abuse"、"alcohol"、"cocaine"、"opioid"、"smokers"、"smoking"、"heroin"、"stimulants"、"methamphetamine"、"gambling"、"gaming"、"internet gaming"、"gaming disorder"、"Internet addiction"、"behavioral addiction"、"internet gaming disorder"、"pathological gambling"、"problematic internet use"、"compulsive use"、"pathological use"。

本研究共检索了两个英文数据库、三个中文数据库：其中英文数据库在 **2023 年 11 月 16** 日进行的检索，地址为：PubMed (https://pubmed.ncbi.nlm.nih.gov/advanced/)、Web of Science (http://www.webofknowledge.com)；之后，对中文文献进行了补充，对 **CNKI**(2024 年 4 月 5 日)、**万方**(2024 年 5 月 30 日)和**维普**(2024 年 5 月 31 日)进行了全面的检索。

编码质量：为了保证元分析结果的可复现和编码质量，目前研究所有步骤都留有记录。除初筛(除去明显不符合文献，如综述、非磁共振研究、非物质或行为成瘾研究等)文献外，目前研究进行了两次重复筛查，以确保符合目前研究标准文献纳入。

文献**年代范围**及其**纳入多少条文献**：物质成瘾共包含 22 项抑制控制任务，9 项奖赏加工任务和 17 项渴求诱导任务文章。行为成瘾共包含 15 项抑制控制任务，22 项奖赏加工任务和 12 项渴求诱导任务文章。目前研究共包含 **97 篇**纳入分析文章。这些文献年代范围从 2003 年到 2023 年，时间跨度 20 年。

3 本元分析是否进行了文献质量及出版偏差评估，如何评估？

答：

已经对文献质量进行了评估。目前研究对**文献质量评估**参照的是 Qiu 和 Wang(2021)的元分析文章。该评估问卷共包含 3 个维度，一共包含 9 个项目。第一维度，被试：1、是否应用特定的诊断标准对患者进行评估，并报告人口统计学数据。2、对健康对照被试进行评估，排除精神疾病和医疗疾病。3、通过分层或统计学方法检查重要变量（如年龄、性别、疾病持续时间、发病、药物状态、合并症、疾病严重程度）。第二维度，图像采集和分析方法：4、使用全脑分析，没有事先的选择脑区。5、使用标准空间模板报告的坐标。6、对所使用的成像技术进行了清楚的描述，以便能够重现。7、对测量结果进行了清晰的描述，以便能够重现。第三维度，结果和结论：8、提供了显著差异和重要非显著差异的统计参数。9、结论与所获得的结果一致，并讨论了其局限性。每个项目分数为 0/0.5/1。完全没做为 0 分，部分重现为 0.5 分，完全按照标准执行为 1 分。详细结果请见发送到编辑部的附件，**质量评估.xlsx**。

本研究采用 ALE 软件进行神经成像元分析计算，未能考虑纳入文章可能存在的出版偏差。

4. 本元分析效果量如何计算？

答：

按研究对象的不同，元分析方法可以分为：基于神经成像数据的元分析，如激活可能性估计法(Activation Likelihood Estimation, ALE)、多水平核密度分析法(Multi-level Kernel Density Analysis, MKDA)和差异图标记分析法(Signed Difference Map analysis, SDM)；和基于传统元分析的效应量(effect size)统计分析。其中 ALE 由于方法上的合理性和使用上的便利，成为当前使用最广泛的基于坐标的元分析方法。ALE 原理是分别计算每个实验中某种条件下全脑范围内每个体素的激活可能性(Activation Likelihood)，然后检验体素跨实验激活的稳定性。因此，目前研究采用了 ALE。在该算法种不用考虑效应量计算。

5. 本元分析是否已注册？如果已注册，请提供注册网址及注册编号。（我们强烈推荐元分析论文研究前预注册，未预注册元分析很可能在初审阶段被直接退稿）本刊预注册网站是 https://os.psych.ac.cn/preregister (使用说明书见本刊网站“下载中心”)

答：

本元分析文章已经在预见心理学预注册平台进行了注册(https://os.psych.ac.cn/preregister)，其注册编号为 202406.00001。

6. 是否有类似的元分析发表过？如果有, 请列出(包括作者姓名、题名、刊名、年卷期和页码), 并说明你与别人的文章有何实质性区别？(必要时需引用, 引导感兴趣的读者去查阅本文没有包含的内容。)

答：

到目前研究为止，我们共收集到三篇相似主题的元分析文章。分别为：

Thang M.Le, Sť ephane Potvin, Simon Zhornitsky, Chiang Shan R. Li. Distinct patterns of prefrontal cortical disengagement during inhibitory control in addiction: A meta-analysis based on population characteristics. Neuroscience and Biobehavioral Reviews. 127. 255–269

Zeguo Qiu, Junjing Wang. Altered neural activities during response inhibition in adults with addiction: a voxel-wise meta-analysis. Psychological Medicine. 12(3). 387–399

Maartje Luijten, Arnt F. Schellekens, Simone Kühn, Marise W. J. Machielse, Guillaume Sescousse. Disruption of Reward Processing in Addiction: An Image-Based Meta-analysis of Functional Magnetic Resonance Imaging Studies. JAMA psychiatry. 74(4). 387-398

本文与前人研究存在两个本质区别：1、先前研究往往局限于某一领域，未能综合不同类型任务分析神经机制改变。同一类任务可能仅仅反应成瘾被试在某种认知加工过程变化，而不同类型任务综合才能更系统性探究成瘾整体变化。2、研究方法不同。先前研究得出物质和行为成瘾区别，均是通过物质成瘾 vs 健康对照组和行为成瘾 vs 健康对照组，如 Luijten 等人(2017)仅仅计算了 Substance addicted vs controls 和 Gambling addicted vs controls，而没有进一步进行对比分析，直接比较两种成瘾在奖赏相关任务中的变化。因此，目前研究更进一步，通过对比分析直接比较两组之间差异。

7. 第一作者或通讯作者是否发表过该元分析主题的相关实证研究？如“是”，请给编辑部（xuebao@psych.ac.cn）发邮件，列出相关论文清单。如“否”，请改投他刊。

答：

作者已经发表过行为成瘾相关实证研究。在这里列出五篇相关研究：

Bai, Y., Elhai, J. D., Montag, C., & Yang, H. (2023). Biased processing of game-related information in problematic mobile gaming users. *Journal of Behavioral Addictions, 12*(2), 480–489. https://doi.org/10.1556/2006.2023.00031

Elhai, J. D., Gallinari, E. F., Rozgonjuk, D., & Yang, H. (2020). Depression, anxiety and fear of

missing out as correlates of social, non-social and problematic smartphone use. *Addictive Behaviors*, 105, 106335. https://doi.org/10.1016/j.addbeh.2020.106335

Elhai, J. D., Yang, H., & Levine, J. C. (2020). Applying fairness in labeling various types of internet use disorders. *Journal of Behavioral Addictions, 9*(4), 924–927. https://doi.org/10.1556/2006.2020.00071

Guo, Y., Elhai, J. D., Montag, C., Wang, Y., & Yang, H. (2024). Problematic mobile gamers have attention bias toward game social information. *Computers in Human Behavior, 152*, 108074. https://doi.org/10.1016/j.chb.2023.108074

Yang, H., Wang, Z., Elhai, J. D., & Montag, C. (2022). The relationship between adolescent emotion dysregulation and problematic technology use: Systematic review of the empirical literature. *Journal of Behavioral Addictions, 11*(2), 290–304. https://doi.org/10.1556/2006.2022.00038

8. 本刊要求作者提供原始数据, 请在以下 4 种里选择一种打√:

a)投稿后将数据发至编辑部邮箱 **(√)**

b)数据可以从如下链接中获得 ________________________ ( )

c)原始数据和程序已在心理科学数据银行(https://psych.scidb.cn/)上分享 ( )

d)如不能提供，请说明理由或提供有关证明。

9. 摘要是否有实质性内容？（摘要作为一个被数据库收录的独立单位，应给读者实质性信息。应当包括：要研究解决的科学问题，参与元分析的文献数量和分析的变量，研究的结论，研究的理论贡献。）

答：

要研究解决的**科学问题**：虽然物质成瘾和行为成瘾在抑制控制、线索渴求诱导和奖赏加工任务上均表现出异常激活，但尚不清楚两者神经机制的相似性和特异性。因此，研究使用激活似然估计(activation likelihood estimation, ALE)分别计算物质成瘾和行为成瘾在抑制控制、线索渴求诱导和奖赏加工任务的激活。之后，进行联合分析和对比分析，探究不同任务下物质成瘾和行为成瘾相似性和特异性激活。

参与元分析的文献数量和分析的变量：研究共纳入 97 篇抑制控制、线索渴求诱导和奖赏加工的物质成瘾和行为成瘾磁共振文献。

研究结果：

(1)在抑制控制相关任务中，物质成瘾者和行为成瘾者不存在相同激活脑区，但物质成

瘾者背外侧前额皮层激活降低，行为成瘾者背外侧前额叶皮层激活增加。

(2)在奖赏加工相关任务中，物质成瘾者和行为成瘾者额下回均表现出异常激活增加，物质成瘾者纹状体激活强于行为成瘾者。

研究结果表明，物质成瘾者和行为成瘾者在纹状体和前额叶存在相似和特异性的激活模式，物质成瘾者在抑制控制环路和奖赏加工环路上出现异常激活，行为成瘾者的奖赏加工环路表现出异常激活。

10. 文中引用的文献与文后的参考文献是否一一对应？（建议使用 EndNote、NoteExpress 等软件来管理参考文献）

答：

本文使用 Zotero 软件进行文献管理和引用确保引用文献和参考文献一一对应。

11. 是否请过同事对投稿进行挑剔性阅读？

答：

在完成文章写作后，本文已经经过挑剔性阅读并进行了更改。

12. 作者信息是否删除？包括 word 文档属性中的作者与单位、基金号、英文摘要中的作者与单位等。

答：

提交稿件已经删除作者、单位、基金号、英文摘要中的作者与单位等敏感信息。

13. 如果第一作者是学生，请导师单独给编辑部（xuebao@psych.ac.cn）发邮件，说明已阅读本文并认真把关。是否已提醒导师给编辑部发邮件？（编辑部收到导师邮件后才会考虑进入稿件处理流程）

答：

投稿前，已经提醒导师给编辑部发邮件

14. 请到编辑部网站首页右侧“下载中心”下载并填写“稿件不涉密证明”，加盖通讯作者单位的保密办公章，把扫描件发至编辑部邮箱（xuebao@psych.ac.cn）。如没有保密办公章，请加盖通讯作者的单位公章。是否已发邮件？

答：

投稿前，已经将加盖通讯作者的单位公章发送给编辑部邮箱。

物质成瘾者和行为成瘾者在纹状体和前额叶脑区激活的异同：基于任务类型的元分析研究

虽然物质成瘾者和行为成瘾者在抑制控制、线索渴求诱导和奖赏加工等任务上均表现出异常模式，但尚不清楚两者神经机制的相似性和特异性。本研究使用激活似然估计(activation likelihood estimation, ALE)分别计算物质成瘾者和行为成瘾者在抑制控制、成瘾物刺激加工和奖赏加工等不同任务下脑激活模式的相似性和特异性。结果发现：(1)在抑制控制相关任务中，物质成瘾者背外侧前额皮层激活降低，行为成瘾者背外侧前额叶皮层激活增加。(2)在奖赏加工相关任务中，物质成瘾者和行为成瘾者额下回激活均增加，物质成瘾者纹状体激活强于行为成瘾者。研究结果表明，在冲动系统上，物质成瘾者和行为成瘾者激活异常；在反思系统上，物质成瘾者反应受损，行为成瘾者补偿性激活。

关键词 元分析; 物质成瘾; 行为成瘾; 奖赏加工; 抑制控制

1 前言

成瘾是一种慢性复发的疾病，其核心特征是患者明确地知道自己的行为有害但是却无法有效的控制成瘾行为(Zeng et al., 2023)。根据是否摄入药物，可将成瘾分为物质成瘾和行为成瘾。物质成瘾是由于药物摄入导致的成瘾性行为；而行为成瘾是通过认知而非直接的药物影响，导致的成瘾性行为。两类成瘾都存在认知和动机功能受损、对成瘾线索的渴求感增强、偏于奖赏而忽视风险以及冲动控制功能障碍等典型性特征(贺金波 等, 2017)。但是，由于成瘾模式差异，物质成瘾者和行为成瘾者认知异常存在区别(Chen et al., 2017)，如在Stroop 任务中，尼古丁依赖个体正确率低于网络游戏成瘾个体(Yan et al., 2021)。可见，物质成瘾者和行为成瘾者认知异常存在相似性和特异性。为进一步揭示物质成瘾和行为成瘾神经机制变化，基于任务态的功能磁共振成像(fMRI)探讨了不同认知任务和成瘾类型下的神经活动规律。

对物质成瘾者和行为成瘾者认知异常的神经机制研究主要存在两种不同倾向(Turel & Qahri-Saremi, 2016)。其一，从冲动系统(impulsive system)的角度，研究者认为在物质成瘾和行为成瘾发展过程中行为逐渐被成瘾相关信息所控制，这些信息通过巴甫洛夫条件反射和工具性学习机制自动产生成瘾性行为和渴求(Noel et al., 2013)。在该过程中，药物或行为与多巴胺系统所产生的强烈激活反复关联配对，从而使奖赏相关神经系统敏感性增加。其二，从反思系统(reflective system)角度，探究成瘾个体在多巴胺系统敏化情况下抑制控制能力变化。研究者认为多巴胺系统敏化会导致成瘾个体抑制控制的降低(Brand et al., 2019; Qiu & Wang, 2021)。当然，这两种研究倾向既相互冲突，又互为补充。从认知神经科学角度来看，成瘾就是由于冲动系统和反思系统之间的平衡被打破，导致成瘾者在面对成瘾刺激物时不能有效控制行为，从而表现出对成瘾线索的渴求感增强、偏于奖赏而忽视风险以及冲动控制功能障碍(贺金波 等, 2017; Turel & Qahri-Saremi, 2016)。如根据 Brand(2022)提出的成瘾发展模型(图 1)，虽然划分了成瘾前期的 feel better 环路和后期的 must do 环路，但是其核心仍然是强调冲动系统和反思系统的相互影响。然而，虽然目前多数研究分别从冲动系统或反思系统角度解释物质成瘾或行为成瘾，但通常都只关注某一成瘾类型下单一模式变化(Luijten et al., 2017; Qiu & Wang, 2021)。因此，在冲动系统和反思系统框架下，物质成瘾者相对行为成瘾者脑激活模式有哪些相似性和特异性变化还需要进一步研究。

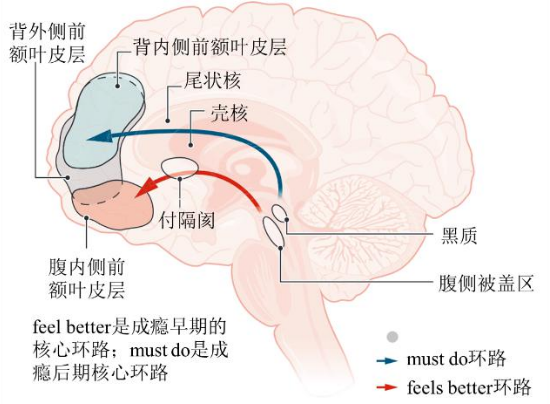

图 1 “feels better”和“must do”两系统；该模型认为成瘾分为前期的“feels better”阶段和后期的“must do”阶段。“feels better”主要通过的是腹侧纹状体，“must do”主要通过背外侧纹状体。“feels better”主要由腹侧被盖区(Ventral tegmental area)、付隔核(Nucleus accumbens)和腹内侧前额叶皮质(Ventromedial prefrontal cortex)组，而“must do”主要由黑质(Substantia nigra)到达壳核(Putamen)、尾状核(caudate nucleus)和背外侧前额叶皮层(Dorsolateral prefrontal cortex)组成；

1.1 物质成瘾者和行为成瘾者冲动系统变化

冲动系统(杏仁核-纹状体系统)异常在成瘾过程理论中占主导地位。正是由于成瘾刺激物反复同有吸引力的、“wanting”激励表征相匹配，从而该改变了刺激物感知，赋予了刺激物更强的显著性，从而使成瘾者对刺激物表现出渴求(Robinson & Berridge, 1993)。而这种反复的激活也损伤了冲动系统，改变个体奖赏敏感性，从而使个体倾向于获得奖赏而忽视风险(Noel et al., 2013)。正是在基于冲动系统框架下，研究者发现物质成瘾者和行为成瘾者在奖赏加工和线索渴求等相关任务上表现出异常激活模式(贺金波 等, 2017)，而进一步的研究也证实了物质成瘾者和行为成瘾者脑激活模式存在相似性和特异性变化。

物质成瘾者和行为成瘾者在奖赏任务中纹状体环路存在异常激活模式。通过对比物质成瘾者和行为成瘾者奖赏相关任务激活脑区，发现相似和特异性变化主要集中在纹状体环路。如 Luo 等人(2011)发现延迟奖赏任务中，尼古丁依赖者在即时奖赏条件下双侧腹侧/背侧纹状体激活增强。同样，Wang 等人(2021)发现轮盘时间任务中网络游戏成瘾个体，在奖励预期和奖励结果阶段纹状体(伏隔核和尾状核)激活增加。而进一步研究发现物质和行为成瘾虽然存在相同激活脑区，但是这些脑区激活方向却相反。Luijten 等人(2017)按照奖赏过程，即奖赏预期阶段和奖赏结果呈现阶段，对物质成瘾者和行为成瘾者脑激活模式变化进行了元分析。结果发现，在奖赏预期阶段，物质成瘾者和赌博成瘾者的纹状体激活降低；在奖赏结果呈现阶段，物质成瘾者腹侧纹状体激活增加，而赌博成瘾者背侧纹状体激活降低。因此，物质成瘾者和行为成瘾者在纹状体环路上均存在异常激活，但这种激活的方向和脑区可能存在差异。此外，有研究者指出这些研究结果仅仅是基于推论，而非直接比较不同物质成瘾者和行为成瘾者脑激活模式差异(Romanczuk-Seiferth et al., 2015)。因此关于

物质成瘾者和行为成瘾者在哪些脑区表现出相似性和特异性脑激活模式还需要更直接的方法进行探讨。

基于上述观点，一些研究开始在同一任务中直接比较物质成瘾者和行为成瘾者，以探究物质成瘾者和行为成瘾者脑激活模式特异和相似性变化。这些研究结果同样发现，物质成瘾者和行为成瘾者在纹状体环路上存在相似性和特异性变化。Worhunsky 等人(2014)研究发现，与可卡因成瘾和健康被试相比，赌博成瘾个体在奖励预期阶段腹侧纹状体、脑岛和内侧前额叶皮层激活增强；而相对于赌博成瘾和健康被试，可卡因成瘾在损失预期阶段奖励相关区域激活降低。结果证实了可卡因成瘾和赌博成瘾共享纹状体异常，通过直接比较也发现可卡因成瘾和赌博成瘾纹状体系统激活模式存在差异。但是，该结果仅仅局限于可卡因成瘾和赌博成瘾范围内。因此，有必要通过大规模数据合并方法，以明确物质成瘾者和行为成瘾者在奖赏任务中冲动系统特异性和相似性变化。

与奖赏任务相同，在探索冲动系统的线索渴求诱导任务中，物质成瘾者和行为成瘾者也存在纹状体系统激活异常。如，研究发现酒精依赖者在观看酒精相关线索时腹侧纹状体激活增加(Wrase et al., 2007)，网络游戏成瘾被试在观看游戏线索时纹状体、黑质激活增加(Liu et al., 2017; Zhang et al., 2016)。此外，物质成瘾者和行为成瘾者在前额叶和扣带回皮层也存在相似和独特激活。研究发现，可卡因成瘾被试在刚开始观看可卡因相关视频时前扣带皮层/腹内侧前额叶皮层(ACC/vmPFC)激活就增加，但病理性赌博被试在刚开始观看赌博相关视频时前扣带皮层/腹内侧前额叶皮层激活却不显著；而在线索视频诱导已经进行一段时间且快要结束时，背内侧前额叶皮层/背侧前扣带回(dmPFC/dACC)出现了渴求诱导视频和成瘾类型交互，病理性赌博被试在赌博相关视频中该区激活增加，而可卡因成瘾被试在可卡因相关视频中该区激活增加(Kober et al., 2016)。可以看出，病理性赌博并不像可卡因成瘾接触相应成瘾刺激物前额叶就出现异常反应；病理性赌博异常激活可能是随着时间推移才显现出来。因此，前额叶和前扣带回可能是理解和区分物质成瘾者和行为成瘾者在线索渴求诱导任务中脑激活模式相似性和特异性的重要中枢。

1.2 物质成瘾者和行为成瘾者反思系统变化

虽然冲动系统异常是导致成瘾行为的一个重要因素，它是产生"wanting"和“must do”成分以寻求奖励的关键。但它并不能解释一个人为何不能有效控制自己的行为。该功能涉及"反思系统"，它是为了控制更基本的冲动，是个体更灵活地追求长期目标所必需的(Noel et al., 2013)。相关研究已经发现物质成瘾者和行为成瘾者在抑制控制相关任务上反思系统的异常激活(Luijten et al., 2015; Schulte et al., 2012)。而进一步研究通过比较物质成瘾者和行为

成瘾者在抑制控制任务中脑区激活，发现物质成瘾者和行为成瘾者异常脑区主要集中在前额叶和扣带回。如物质成瘾被试和行为成瘾被试均发现抑制控制任务共同激活了背外侧前额叶皮层(Jan et al., 2014; Shen et al., 2023)、前扣带回(Czapla et al., 2017; Dong et al., 2013)。另一方面物质成瘾者和行为成瘾者抑制控制任务下神经机制也存在分离。在抑制控制任务中，网络游戏成瘾个体前扣带回/背外侧前额叶皮层激活增加(Yao et al., 2017)，而大麻使用者激活却降低(Ceceli et al., 2023; Kober et al., 2014)。同样，Picó-Pérez 等人(2022)直接比较可卡因使用障碍和赌博障碍情绪调节能力，发现可卡因使用障碍背侧注意网络激活异常，而赌博障碍却未发现显著激活(Picó-Pérez et al., 2022)。因此，物质成瘾者和行为成瘾者在抑制控制任务中存在脑激活相似变化，但是两者在具体激活模式可能也存在分离。

可见，在冲动系统和反思系统框架下，物质成瘾者和行为成瘾者存在相似性和特异性的激活脑区。相似激活脑区反映了物质成瘾者和行为成瘾者共同因素的影响，而特异激活脑区可能反映了不同类型成瘾刺激物特异性地影响。综合分析已有的研究可以得出，目前研究已经确定了物质成瘾者和行为成瘾者确实存在相似的神经机制(Tolomeo & Yu, 2022; von Deneen et al., 2022)，总的来看物质成瘾和行为成瘾在奖赏加工、线索渴求诱导、抑制控制等任务中纹状体、扣带回、前额叶等脑区确实均存在异常(Le et al., 2021)。但还需要进一步研究明确揭示物质成瘾者和行为成瘾者相似和特异性脑激活模式。首先，先前研究结果多数是通过间接推论而不是直接比较，得出不同类型成瘾脑区激活相似性和特异性变化(Luijten et al., 2017)。其次，虽然已经有元分析从奖赏加工和抑制控制角度探究了物质成瘾者和行为成瘾者异常激活(Le et al., 2021; Luijten et al., 2017)。但是之前少有研究探究物质成瘾者和行为成瘾者脑激活模式相似和特异性。先前研究往往局限于某一领域，未能综合不同类型任务分析神经机制改变。在某一类型任务探究物质成瘾者和行为成瘾者功能相似和特异性变化，可能仅仅反映成瘾者在某种认知加工过程变化，而不同类型任务综合分析才能更系统性探究物质成瘾者和行为成瘾者整体变化特点。

基于体素的激活可能性估计法(ALE)的元分析已经广泛用于探究磁共振相关研究一致性激活(胡传鹏等, 2015; Tolomeo & Yu, 2022)，可以分别对物质成瘾和行为成瘾的各任务类型激活模式进行一致性检验。同时，通过对比分析，也能探讨物质成瘾者和行为成瘾者在同一类型任务上激活的相似性和特异性(刘俊材 等, 2022)。基于此，本研究使用激活可能性估计法，以探究物质成瘾者和行为成瘾者大脑活动在反映冲动系统和反思系统的任务下相似性和特异性激活(胡传鹏等, 2015)。

2 方法

2.1 文献检索

在 2023 年 11 月 16 日对 PubMed 和 Web of Science 进行了全面的文献检索。使用"neuroimaging"、"functional MRI"、"fMRI"、"functional Magnetic Resonance Imaging"和"addiction"、"substance use disorder"、"substance abuse"、"alcohol"、"cocaine"、"opioid"、"smokers"、"smoking"、"heroin"、"stimulants"、"methamphetamine"、"gambling"、"gaming"、"internet gaming"、"gaming disorder"、"Internet addiction"、"behavioral addiction"、"internet gaming disorder"、"pathological gambling"、"problematic internet use"、"compulsive use"、"pathological use"为关键词进行组合。之后对中文文献进行了补充，对 CNKI(2024 年 4 月 5 日)、万方(2024 年 5 月 30 日)和维普(2024 年 5 月 31 日)进行了全面的检索。中文关键词为，神经成像、磁共振和成瘾、物质成瘾、行为成瘾、酒精、可卡因、阿片、尼古丁、海洛因、冰毒、游戏、网络成瘾、网络游戏成瘾、赌博、病理性赌博。

2.2 文章选取标准

为了获取元分析目标文章，定下了如下排除标准。1、非磁共振文章；2、不是物质成瘾者或行为成瘾者的文章；3、非人类研究不予与采纳；4、药物治疗研究不予与采纳；5、文献需为实证研究，综述、元分析及个案研究不予与采纳；6、文章需要经过同行评审并发表，硕士和博士论文不予与采纳。随后对纳入文章进行进一步的评价，其排除标准：1、非任务态磁共振文章；2、研究采用全脑分析，排除只进行基于兴趣区(ROI)的研究；3、成瘾组脑区坐标不是通过与健康对照组相比较得出的；4、未达到 DSM 或者成瘾问卷标准的文章不予与采纳；5、存在结果但未在文中标注出来。

2.3 激活似然估计法

本研究使用的是由 Turkeltaub 等人(2002)开发，基于激活可能性估计法的 GingerALE 软件。该研究使用了 GingerALE 3.0.2 版本。它依靠激活可能性估计法(ALE)来比较从多篇文章提取出来的坐标，并估计重叠的程度，以及在统计上最有可能激活的 cluster。通过 GingerALE (3.0.2)将研究中获得的 Talairach 坐标转换为 MNI 空间坐标。之后将转化好的坐标与已有 MNI 研究坐标合并在一起并导入到软件中。然后，在三种不同任务条件下，分别对物质和行为成瘾进行单一元分析，设置阈值 $p<0.001$，cluster 的最小体积为 250mm^3。最后，在三种不同任务下，分别对物质成瘾和行为成瘾进行对比分析，从而探究不同任务条件下物质成瘾者和行为成瘾者的差异和共同激活脑区。对比分析的阈值设置为 $p < 0.01$

（未校正），且最小团块大于 $50mm^3$(10000 排列)。在本研究分析中使用以下六种对比来检查任务态磁共振激活的组间差异：物质成瘾 > 对照组；物质成瘾 < 对照组；行为成瘾 > 对照组；行为成瘾<对照组；物质成瘾 > 行为成瘾；物质成瘾 < 行为成瘾。

3 结果

3.1 纳入文献和样本特征

共搜索并产生了 19683 篇论文，并筛选出了 86 篇物质成瘾文章和 62 篇行为成瘾文章。图 2 展示了文献筛选过程。除了抑制控制、奖赏加工、线索渴求诱导任务外，其他物质成瘾或行为成瘾领域文章较少，不能进行对比分析。因此，表 1 和表 2 只展示了物质成瘾和行为成瘾在抑制控制、奖赏加工和渴求诱导方面具体纳入文章的基本情况。其中，物质成瘾共包含 22 项抑制控制任务，9 项奖赏加工任务和 17 项渴求诱导任务文章。行为成瘾共包含 15 项抑制控制任务，22 项奖赏加工任务和 12 项渴求诱导任务文章。在这三项任务中，物质成瘾研究共纳入 2183 被试，包含 1145 名成瘾者(男性成瘾者 917 名、女性成瘾者 228 名)，对照组被试包含 1038 名(男性对照组被试 763 名，女性对照组被试 275 名)；行为成瘾研究共包含 1924 被试，包含 943 名成瘾者(男性成瘾者 852 名，女性成瘾者 91 名)；对照组被试包含 928 名(男性对照组被试 842 名，女性对照组被试 86 名)。行为成瘾有一篇文章没有明确报告性别，其中包含 27 名成瘾者和 26 名健康对照组。

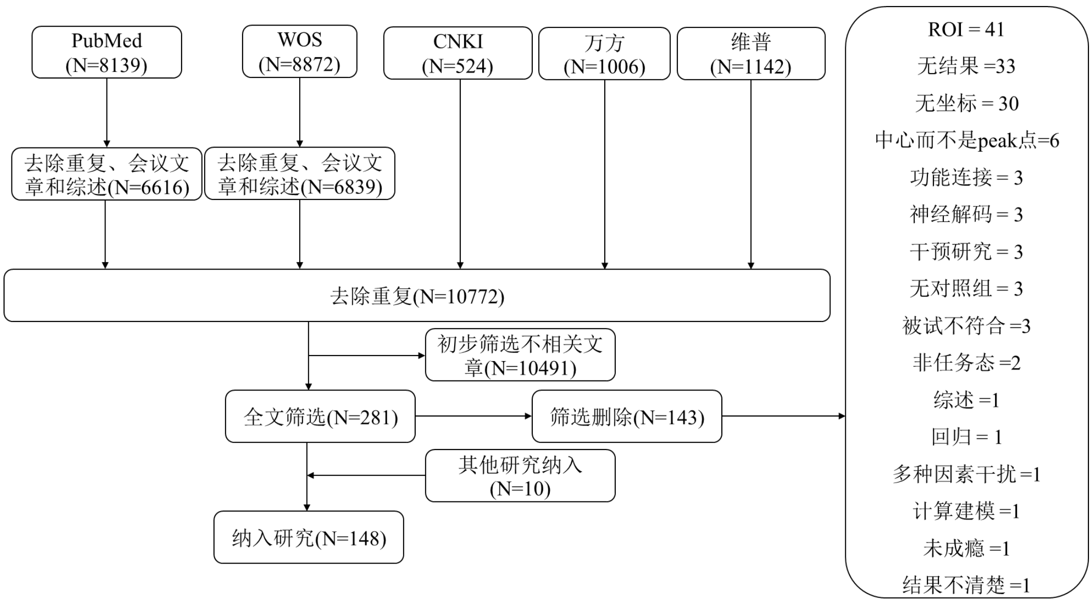

图 2 研究选择流程图

表 1 物质成瘾全脑 fMRI 总结

作者	成瘾组		成瘾组平均年龄 (M±SD)	对照组		对照组平均年龄 (M±SD)	成瘾物类型	任务
抑制控制	男	女		男	女			
Czapla et al., (2017)	17	2	51.21 ± 7.36	17	4	41.95 ± 9.99	酒精	Go/no-go
Jan et al., (2014)	7	0	38.3 ± 5.6	7	3	32.3 ± 8.7	冰毒	Stroop
Stein et al., (2021)	10	3	45.62 ± 10.01	9	5	37.71 ±12.82	酒精	Go/no-go
Li et al., (2009)	18	6	38.7 ± 8.3	18	6	35.5 ± 5.9	酒精	Stop signal task
Ceceli, Parvaz et al., (2023)	24	4	44.07 ± 8.18	21	5	42.66 ± 7.05	可卡因	Stop signal task
Müller-Oehring et al., (2019)	10	8	49.6 ± 11	17	4	50.3 ± 9.5	酒精	Addiction-stroop color match-to-sample task
Kober et al., (2014)	20		26.65 ± 9.81	20		29.20 ± 10.06	大麻	Stroop color-word interference task
Fu et al., (2008)	28		33.39 ± 5.98	15		29.59 ± 6.94	海洛因	Go/no-go
Ma et al., (2015)	12	1	37.4 ± 5.3	7	3	35.2 ± 7.3	可卡因	Easy no-go
Zerekidze et al., (2023)	14	4	32.4 ± 7.4	14	7	27.6 ± 3.5	冰毒	Stroop task
Li et al., (2008)	15		37.7 ± 6.8	15		36.6 ± 6.0	可卡因	Stop signal task
Nestor et al., (2011)	5	5	33.5 ± 9.3	11	7	36.4 ± 10.4	冰毒	Color-world stroop
Albein－Urios et al., (2014)	16	1	36.41±5.99	17	1	30.50 ± 4.64	可卡因	Re-appraisal task
Gerhardt et al., (2021)	13	2	47 ± 12.3	9	6	41.9 ± 14.4	酒精	Simon-task & Go-/no-no & Stop-signal trials
Schulte et al., (2017)	18	8	49.9 ± 9.5	17	9	49.1 ± 11	酒精	Priming alcohol-emotion stroop
Ceceli, King et al., (2023)	31	9	40.9 ± 9.20	15	9	41.7 ± 11.3	海洛因	Stop-signal task
Huang et al., (2023)	25	7	40.25 ± 8.82	13	8	40.58 ± 10.84	海洛因	Drug cue reappraisal
Cyr et al., (2019)	17	11	19.3 ± 2.0	17	15	18.9 ± 2.7	大麻	Simon task
Ceceli, Huang et al., (2023)	18	7	40.6 ± 9.1	15	9	41.1 ± 10.8	海洛因	Stop-signal task
Moeller et al., (2012)	28	5	44.2 ± 6.3	17	3	39.8 ± 5.0	可卡因	Stroop

Schulte et al., (2012)	18		51 ± 6.6	17		50 ± 14.9	酒精	Stroop match-to-sample task
富丽萍等人(2008)	30		33 ± 6	18		29 ± 7	海洛因	Go/no-go
奖赏加工								
Grodin et al., (2016)	11	6	32.25 ± 6.94	9	8	27.72 ± 4.25	酒精	Monetary incentive delay task
Jia et al., (2011)	12	8	38.6 ± 9.29)	12	8	35.25 (10.19)	可卡因	Monetary incentive delay task
Gilman et al., (2015)	12	6	30.50 ± 5.06	12	6	30.67 ± 7.10	酒精	Risk-taking task
Monterosso et al., (2007)	8	4	33.8 ± 8.1	12	5	29.7 ± 7.2	冰毒	Delay discounting task
Goldstein et al., (2007)	12	4	42.8 ± 4.6	9	4	37.6 ± 6.8	可卡因	Forced-choice task
Dennis et al., (2020)	29	10	-	28	18	35 ± 11.80	酒精	Probabilistic delay discounting task
Luo et al., (2011)	20	15	34.1 ± 7.9	23	13	31.3 ± 7.1	尼古丁	Modified monetary incentive
Wesley et al., (2014)	20	5	34.7 ± 20.9	13	12	39.9 ± 22.2	可卡因	Two cross-commodity temporal decision-making tasks
Filbey et al., (2013)	46	13	23.49 ± 6.37	5	22	30.32 ± 10.09	大麻	Monetary incentive delay task
线索渴求诱导								
李强等人(2013)	18		34.6 ± 6.8	20		35 ± 7	海洛因	线索渴求诱导
Goudriaan et al., (2010))	10		-	17		34.7 ± 9.7	尼古丁	Cue-reactivity task
Heinz et al., (2007)	6	6	39 ± 7	6	6	40 ± 8	酒精	Cue-reactivity task
Huang et al., (2018)	28		31.68 ± 7.06	27		33.93 ± 7.21	冰毒	Cue-reactivity task
Zhou et al., (2019)	18		22.94 ± 2.71	44		23.2 ± 4.32	大麻	Cue-reactivity task
Sjoerds et al., (2014)	16	14	46.5 ± 8.5	11	4	46.8 ± 10	酒精	Cue-reactivity task
Dakhili et al., (2022)	53		32.12 ± 5.89	23		31.17 ± 5.69	MA	Cue-reactivity task
Wrase et al., (2007)	16		42.38 ± 7.52	16		39.94 ± 8.59	酒精	Cue-reactivity task
Seo et al., (2016)	29	8	37.2 ± 7.9	23	14	34.3 ± 8.6	酒精	Cue-reactivity task
Moeller et al., (2018)	28	9		18	8	43.1 ± 7.2	可卡因	Drug-choice task
Schulte et al., (2017)	18	8	49.9 ± 9.5	17	9	49.1 ± 11	可卡因	Cue-reactivity task

Huang et al., (2023)	25	7	40.25 ± 8.82	13	8	40.58 ± 10.84	酒精	Cue-reactivity task
Blaine et al., (2020)	28	16	33 ± 11	23	20	32 ± 10	海洛因	Cue-reactivity task
Tapert et al., (2003)	9	6	16.96 ± 0.78	9	6	16.35± 1.02	酒精	Alcoholic beverage pictures task
Gilman & Hommer et al., (2008)	12		41.83 ± 8.39	12		38.08 ± 6.97	酒精	Visual stimulation task
Li et al., (2012)	24		32.8 ± 6.6	20		35.0 ± 7.0	海洛因	Cue-reactivity task
Hong et al., (2017)	15		39.9 ± 4.9	15		39.2 ± 5.2	尼古丁	Cue-reactivity task

表 2 行为成瘾全脑 fMRI 总结

作者	成瘾组		成瘾组平均年龄	对照组		对照组平均年龄	成瘾物类型	任务
抑制控制	男	女	(M±SD)	男	女	(M±SD)		
Ko et al., (2014)	26		24.58 ± 3.23	23		24.35 ± 2.12	IGD	Go/no-go
Zhang et al., (2016)	19		22.2 ± 3.1	21		22.8 ± 2.4	IGD	Stroop
Wang, Yang, Zheng, Li, Wei et al., (2021)	15		22.60 ± 2.25	25		23.00 ± 2.50	IGD	Stop signal task
Navas et al., (2017)	16	1	32.94 ± 7.77	20	1	31.00 ± 4.60	PG	Cognitive reappraisal task
Ding et al., (2014)	14	3	16.41 ± 3.20	14	3	16.29 ± 2.95	IGD	Go/no-go
Shen et al., (2023)	10	18	-	10	20	-	PMVG	Stroop
Luijten et al., (2015)	18		20.83 ± 3.05	16		21.38 ± 3.03	PG	Go/no-go
Zhang et al., (2021)	21		22.43 ± 2.75	23		21.74 ± 2.49	IGD	Regulation of craving task
Zhang, Dong, et al., (2020)	12	12	20.92 ± 2.38	15	11	20.35 ± 1.83	IGD	Emotional regulation task
Dong, Shen, et al., (2013)	15		23.8 ± 3.7	15		24.1 ± 3.3	IGD	Color-word stroop task
Dong et al., (2012)	12		23.6 ± 3.5	12		24.2 ± 3.1	IGD	Color-word stroop task
Liu et al., (2014)	11		23.45 ± 2.34	11		22.45 ± 1.70	IGD	GO/no-go
Dong et al., (2017)	18		21 ± 2.83	21		22 ± 2.45	IGD	Color-word interference stroop task
Lee et al., (2015)	18		13.6 ± 0.9	18		13.4 ± 1.0	IGD	Stroop match-to-sample task
周于等人(2018)	8	2	15.6 ± 3.1	8	2	15.3 ± 2.9	IGD	Stroop
奖赏加工								
丁伟娜等人(2013)	14	3	16.41 ± 3.2	14	3	16.29 ± 2.95	IGD	概率性猜牌任务
Choi et al., (2012)	15		27.93 ± 3.59	15		26.60 ± 4.29	PG	Monetary incentive task

Balodis et al., (2012)	10	4	35.8 ± 11.7	10	4	37.1 ± 11.3	PG	Monetary incentive delay task
Wang, Yang, Zheng, Li, Qi, et al., (2021)	27		22.52 ± 2.33	26		23.23 ± 2.37	IGD	Timeline of the roulette task
Sescousse et al., (2013)	18		34.1 ± 11.6	20		31 ± 7.3	PG	Incentive delay task
Kim et al., (2017)	18		22.2 ± 2.0	20		21.20 ± 2.2	IGD	The feedback type and experimental paradigm.
Power et al., (2012)	13		42.4 ± 10.8	13		41.0 ± 11.0	PG	Iowa gambling task
Seok et al., (2015)	15		22.20 ± 3.07	15		22.47 ± 2.53	网络成瘾	Financial decision-making task
Lei et al., (2022)	45		20.82 ± 1.37	42		21.29 ± 1.52	IGD	Reward-related prediction-error task
Zhang, Hu, et al., (2020)	29	25	男: 22.77 ± 2.22 女: 21.25 ± 1.56	36	21	男: 23.33 ± 2.04 女: 22.37 ± 1.88	IGD	Card-guessing task
Kim et al., (2014)	15		13.87 ± 0.83	15		13.87 ± 0.83	网络成瘾	Right-left discrimination test
Xiao et al., (2015)	19		22.2 ± 3.08	21		22.8 ± 2.35	IGD	Probability discounting task
Dong, Hu, & Lin (2013)	16		21.4 ± 3.1	15		22.1 ± 3.6	网络成瘾	Reality-simulated guessing task
Schmidt et al., (2021)	25		27.9 ± 9.3)	28		26.8 ± 5.8)	PG	Monetary incentive delay task
Dong, Hu, Lin, et al., (2013)	16		21.4 ± 3.1	15		22.1 ± 3.6	网络成瘾	Continuous win/ losses
Wang, Hu, et al., (2017)	18		22.1 ± 3.2	21		23.1 ± 2.0	IGD	Delay discounting task
Miedl et al., (2012)	15	1	35 ± 2	15	1	38 ± 2	PG	The delay discounting & probabilistic discounting
Dong et al., (2011)	14		23.4 ± 3.3	13		24.1 ± 3.2	网络成瘾	Guessing task
Dong et al., (2017)	18		21 ± 2.83	21		22 ± 2.45	IGD	Guessing task
Miedl et al., (2015)	15		36.7 ± 5.8	15		36.8 ± 5.6	PG	Monetary-choice task
Gelskov et al., (2016)	14		29.43 ± 6.05	15		29.87 ± 6.06	PG	Gambling task
Liu, Xue, et al., (2017)	41		21.93 ± 1.88	27		22.74 ± 2.35	IGD	The cups task
线索渴求诱导								
Liu et al., (2016)	11	8	21.4 ± 1.0	11	8	20.8 ± 1.1	IGD	Internet game video task
Limbrick-Oldfield et al., (2017)	19		31	19		28	PG	Cue-reactivity task
Sun et al., (2012)	10		20.40 ± 1.506	10		20.30 ± 0.675	IGD	Cue-reactivity task
Lorenz et al., (2013)	8		25 ± 7.4	9		24.8 ± 6.9)	PMVG	Dot probe paradigm
Ko et al., (2013)	15		24.67 ± 3.11	15		24.47 ± 2.83	IGD	Cue-reactivity task
Wang, Wu, et al., (2017)	27	3	21.07 ± 1.34	26	4	21.45 ± 1.32	IGD	Cue-reactivity task
Zhou et al., (2021)	10	11	21.29 ± 1.52	15	8	21.61 ± 1.95	IGD	Cue-reactivity task

Liu et al., (2017)	39	22.64 ± 2.12	23	23.09 ± 2.13	IGD	Cue-reactivity task
Zhang et al., (2016)	40	21.95 ± 1.84	19	22.89 ± 2.23	IGD	Cue-reactivity video task
Ko et al., (2009)	10	22	10	22.7	IGD	Cue-reactivity task
Goudriaan et al., (2010)	17	35.3 ± 9.4	17	34.7 ± 9.7	PG	Cue-reactivity task
Crockford et al., (2005)	10	39.3 ± 7.6	10	39.2 ± 8.3	PG	Cue-reactivity task

IGD：网络游戏成瘾障碍(Internet gaming disorder)；PG：问题性赌博(problem gambling)；PMVG：问题性智能视频游戏使用(problematic mobile video gamers)

3.2 元分析结果

3.2.1 物质成瘾和行为成瘾抑制控制的重合和分离

对 22 项物质成瘾抑制控制任务进行单数据分析，结果如表 3 和图 3 所示。物质成瘾者在抑制控制任务中前扣带回、小脑、梭状回、屏状核、岛叶、额中回、海马和尾状核激活增加；额下回、额中回、中央前回、颞中回、颞上回、扣带回、顶下小叶、丘脑底核、额上回激活降低。对 15 项行为成瘾抑制控制任务进行单数据分析。行为成瘾者在抑制控制任务中前扣带回、额中回激活增加。

通过联合分析和对比分析探讨物质成瘾者和行为成瘾者在抑制控制任务上特异性和相似性脑激活模式。结果未发现物质成瘾者和行为成瘾者在抑制控制任务中存在重合或差异激活脑区。

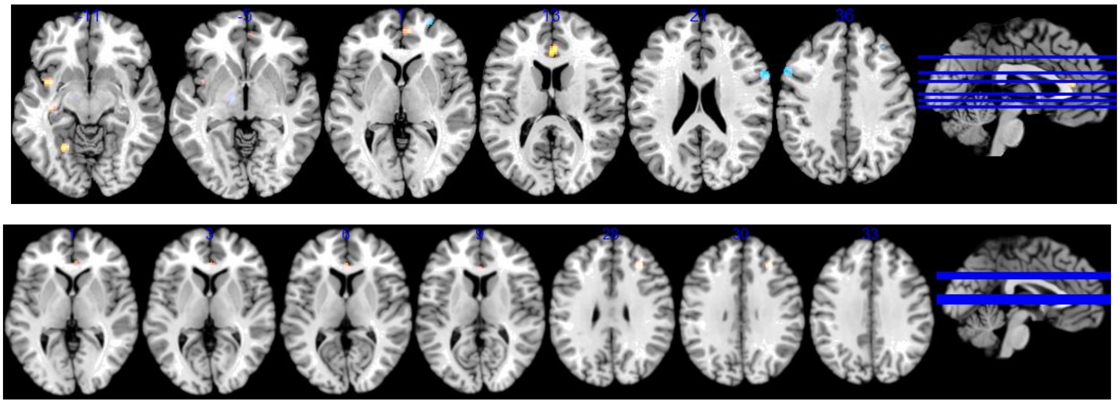

图 3 物质成瘾(上)和行为成瘾(下)抑制控制激活。黄色表示激活增加，蓝色表示激活降低

3.2.2 物质成瘾和行为成瘾线索渴求诱导的重合和分离

由于行为成瘾渴求降低的坐标点较少，因此，在线索渴求诱导任务中，行为成瘾者没有计算渴求降低一致性脑区。分别对 17 项物质成瘾和 12 项行为成瘾线索渴求诱导任务进行单数据分析，结果如表 4 和图 4 所示。物质成瘾在线索渴求诱导任务中前扣带回、额中回、额下回、中央前回、红核、海马旁回、楔前叶和枕中回激活增加，额上回激活降低。行为成瘾在线索渴求诱导任务额下回、扣带回和后叶激活增加。

通过联合和对比分析，探讨物质成瘾者和行为成瘾者在线索渴求诱导任务上特异性和相似性脑激活模式(详细结果见表 4 和图 6)。联合分析结果发现，物质成瘾者和行为成瘾者在线索渴求诱导任务中均激活增加了额下回。对比分析未发现物质成瘾者和行为成瘾者脑区激活存在差异。

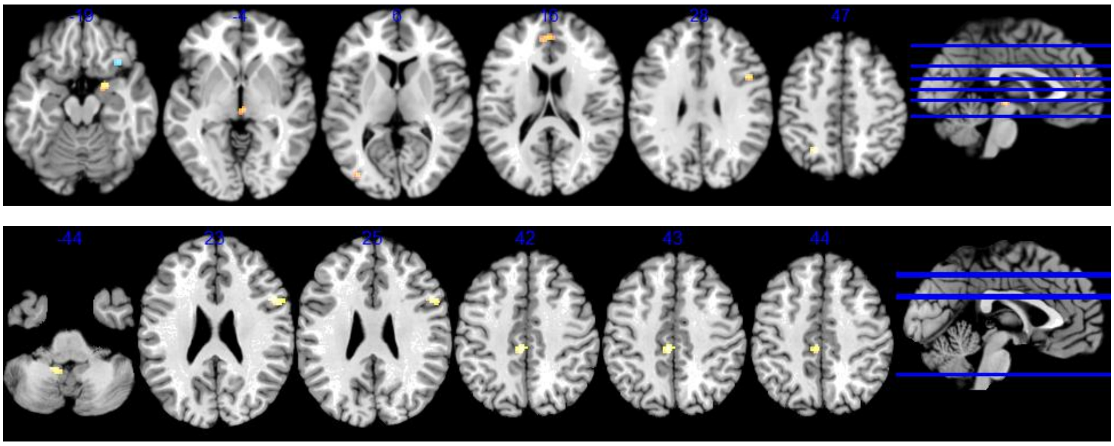

图 4 物质成瘾(上)和行为成瘾(下)渴求诱导激活

3.2.3 物质成瘾和行为成瘾奖赏加工的重合和分离

对 9 项物质成瘾奖赏加工任务进行单数据分析，结果如表 5 所示。物质成瘾者在奖赏加工任务中壳核、楔前叶、顶上小叶、尾状核、黑质激活增加；而舌回、枕中回、梭状回、小脑蚓部山坡、额下回、中央前回、额中回、岛叶和屏状核激活降低(见图 5)。对 22 项行为成瘾奖赏加工任务进行单数据分析，结果发现行为成瘾者在豆状核、尾状核、丘脑、脑岛、颞中回、颞上回、尾状核激活增加；而岛叶、颞上回、额下回、小脑蚓部山坡、前扣带回、枕中回和楔叶激活降低(见表 5 和图 5)。

对奖赏加工相关物质和行为成瘾研究进行联合分析，结果发现物质成瘾者和行为成瘾者没有重叠激活脑区。进一步的对比分析发现，相对于行为成瘾者，物质成瘾者壳核激活更强(见表 5 和图 6)。

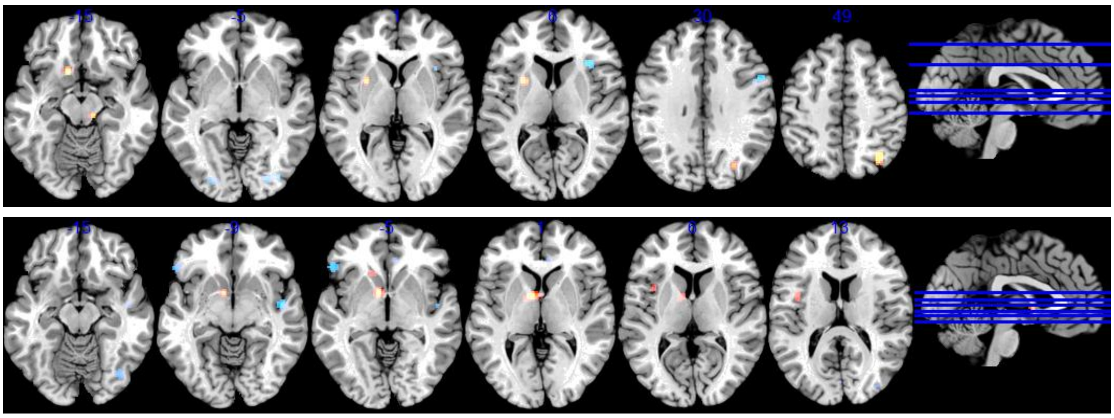

图 5 物质成瘾(上)和行为成瘾(下)奖赏加工激活

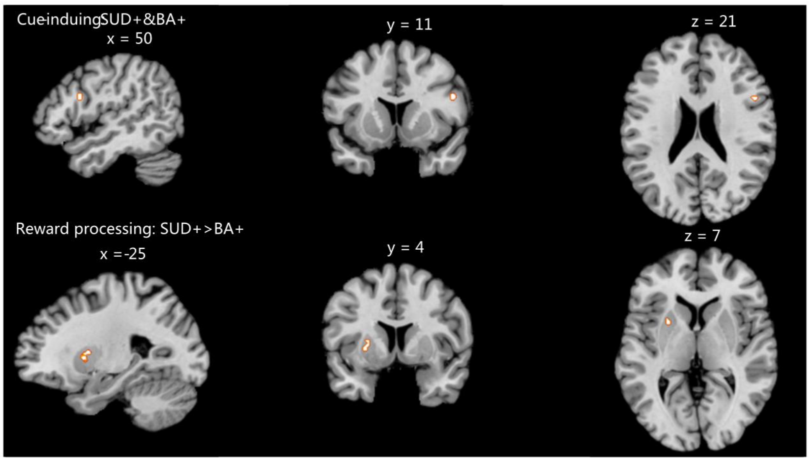

图 6 物质成瘾者和行为成瘾者对比分析和联合分析结果

表 3 物质成瘾和行为成瘾抑制控制激活差异

cluster	体积/mm³	ALE 值/×10⁻³	Z 值	X	Y	Z	BA 区	脑区
SA+								
1	528	13.50	4.36	2	34	10	24	左 前扣带回
2	424	13.93	4.46	-22	-58	-14	19	左 小脑蚓部山顶
3	400	12.89	4.23	-38	3	-10	13	左 屏状核、岛叶
4	384	10.36	3.75	4	50	-2	32/10	右 前扣带回、额中回
5	288	11.07	3.88	-36	-22	-10		左 海马、尾状核
SA-								
1	504	15.27	4.24	62	8	20	9	右 额下回、中央前回
2	480	18.17	4.73	-54	14	38	9	左 额中回、中央前回
3	416	14.53	4.09	54	4	-26	21	右 颞中回
4	392	12.15	3.61	36	30	32	9	右 额中回
		10.22	3.26	38	38	40	9	右 额中回
5	360	15.30	4.25	-44	8	-28	38	左 颞上回
6	360	16.84	4.52	-12	-12	-8		丘脑底核
7	360	14.06	3.99	44	0	48	6	右 中央前回、额中回
8	352	16.39	4.44	26	60	-2	10	右 额上回
9	302	12.68	3.71	18	34	24	32	右 扣带回
		12.67	3.70	18	32	28	9	右 额中回
10	256	14.66	4.12	-60	-28	26	40	左 顶下小叶
BA+								
1	504	10.25	3.94	0	32	4	24	左 前扣带回
1		8.84	3.69	6	36	-2	24	右 前扣带回
2	456	13.47	4.54	30	32	28	9	左 额中回
3	264	9.48	3.81	-16	-12	54	6	右 额中回

注：在单数据分析中 MNI 空间坐标(x, y, z)阈值 $p<0.001$，cluster 的最小体积为 250mm³；对比分析中阈值 $p < 0.01$（未校正），进行 10000 次置换检验，cluster>50；ALE = 激活可能性估计法，BA=行为成瘾，SUD=物质成瘾，+=激活增加，-=激活降低

表 4 物质成瘾和行为成瘾渴求诱导激活差异

cluster	体积/mm^3	ALE 值/×10^{-3}	Z 值	X	Y	Z	BA 区	脑区
SA+								
1	720	12.25	3.73	-6	42	14	32	左 前扣带回
		11.02	3.50	-2	46	16	9	左 额中回
2	528	15.35	4.35	46	8	26	9 6	右 额下回、中央前回
3	400	13.83	4.04	34	34	-12	47	右 额下回
4	384	13.78	4.03	2	-22	-8		左 红核
5	360	13.25	3.92	22	0	-20	34/28	右 海马旁回
6	304	14.58	4.20	-26	-60	44	7	左 楔前叶
7	264	13.19	3.91	-38	-82	8	19	左 枕中回
SA-								
1	280	11.78	4.15	34	22	-18	47/13	右 额下回、脑岛
BA+								
1	472	11.46	3.78	56	10	22	9	右 额下回
		11.39	3.76	52	12	22	9	右 额下回
2	296	10.35	3.55	-14	-48	-42		左 小脑扁桃体
3	272	11.94	3.88	-4	-30	42	31	左 扣带回
SA+&BA+								
1	104	10.80		50	12	22	9	右 额下回

表 5 物质成瘾和行为成瘾奖赏加工激活差异

cluster	体积/mm^3	ALE 值/×10^{-3}	Z 值	X	Y	Z	BA 区	脑区
SA+								
1	760	15.22	4.48	-28	6	4		左 壳核
2	648	15.40	4.53	34	-64	48	19/7	右 楔前叶
3	416	15.64	4.58	-12	14	-14		左 壳核、尾状核
4	384	15.16	4.47	10	-26	-18		右 黑质
5	296	12.55	3.98	30	-72	28	31/18	右 楔前叶

SA-								
1	768	14.35	4.56	34	-84	-6	18/19	右 舌回、枕中回
		12.91	4.25	26	-86	-6		
2	720	13.56	4.38	-28	-86	-10	18/19	左 梭状回、小脑蚓部山坡
		10.15	3.77	-22	-74	-10		
3	600	12.76	4.22	54	8	30	6/9	右 额下回、中央前回、额中回
		12.54	4.18	54	10	38		
		10.61	3.84	48	4	30		
4	472	14.12	4.51	34	22	6	13	右 岛叶、屏状核
BA+								
1	1920	17.73	5.07	-10	0	2		左 豆状核、尾状核、丘脑
		17.18	4.98	-8	4	-6		
2	720	11.75	3.91	-40	-2	14	13	左 脑岛
3	448	15.03	4.61	-51	8	-35	21/38	左 颞中回、颞上回
4	296	10.01	3.59	-14	24	-8		左 尾状核
BA-								
1	736	20.59	5.28	48	-8	-12	13/21/22	右 岛叶
2	616	16.16	4.55	-52	28	-8	47/45	左 额下回
3	448	14.73	4.29	40	-74	-16	19	右 小脑蚓部山坡
4	320	14.05	4.15	8	34	-4	24	右 前扣带回
5	304	14.39	4.22	34	-88	16	19	右 枕中回
6	280	12.05	3.75	6	-82	18	17/18	右 楔叶
SA+>BA+								
1	224		2.37	-25	3	5		左 壳核
			2.35	-28	8	-2		左 壳核
			2.35	-24	8	4		左 壳核

4 讨论

物质成瘾药物能通过影响神经递质的活动(Volkow et al., 2001)，从而让个体保持兴奋，而这种极端的兴奋将损害神经系统和功能。同样，行为成瘾研究也发现了大脑功能的损伤(Yao et al., 2017)。但相对于物质成瘾，行为成瘾是通过认知而非直接的药物影响导致成瘾。因此，行为成瘾和物质成瘾在不同任务上脑激活模式可能存在差异。本研究基于反思系统和冲动系统的双系统理论下，使用激活可能性估计法元分析的方法，确定了物质成瘾者和行为成瘾者在奖赏任务、线索渴求诱导和抑制控制任务下相似和特异的大脑激活模式。

4.1 不同任务下物质成瘾者和行为成瘾者神经机制的重合和分离

单一元分析研究发现，物质成瘾者在抑制控制任务中右额下回、丘脑底核和中央前回激活降低。根据 Hannah 和 Aron(2021)提出的抑制性运动网络理论，大脑在检测到停止信号时，相关的感觉信息会被反馈到前额叶皮层，在前额叶皮层产生停止命令后，丘脑底核接受来自右额下皮层的抑制性信号，并通过基地神经节，进而抑制丘脑对中央前回激活，从而降低运动的可能性。与健康被试相比，物质成瘾者右额下回、丘脑底核和中央前回激活降低，可能表明在抑制信息产生、传递和执行方面存在缺陷。而行为成瘾者并未观察到上述三脑区的异常激活，说明相对于物质成瘾者，行为成瘾者抑制信息的产生、传递和执行可能得到了一定程度保留(Qiu & Wang, 2021)。联合分析结果虽然没有发现物质成瘾者和行为成瘾者在抑制控制任务上存在重合脑区，但是，物质成瘾者和行为成瘾者其前扣带回激活均增加。前扣带回在抑制控制中的独特功能作用可能涉及冲突监测，包括反应竞争和错误处理(Czapla et al., 2017)。该区域在解剖学上与运动和腹侧、背侧纹状体连接，被认为在转移注意力、加强自上而下的控制和选择适当的行动方面发挥着至关重要的作用(Pelliccia et al., 2023)。前扣带回的激活增加说明成瘾者需要付出更大的认知资源才能检测冲突和错误，这可能会降低成瘾者对有害习惯纠错的能力(Le et al., 2021)。

此外，物质成瘾者在线索渴求诱导任务中同样发现了前扣带回激活增加。先前研究表明前扣带回能参与广泛的情绪调节，如恐惧、愤怒、悲伤和快乐(Pelliccia et al., 2023)。前扣带回的激活增加说明成瘾物类型图片诱发了物质成瘾者更强烈的情绪反应，如兴奋等，这种情绪做可能进一步诱导个体寻求成瘾刺激物(Huang et al., 2018)。此外，在渴求诱导任务中行为成瘾者后扣带回激活降低。后扣带皮层除了接收来自顶叶皮层区域的输入外，也接收来自眶额叶皮层的连接，其功能涉及空间注意和奖赏相关刺激的扫视(Rolls, 2019)。因此，在线索渴求诱导任务中，行为成瘾者后扣带回激活增加可能反映了行为成瘾者对成瘾

相关刺激物的注意增强。

先前研究发现，物质成瘾者和行为成瘾者在奖赏加工任务中，纹状体环路中存在广泛的激活(Teicher et al., 2016)。目前研究重复了前人研究结果，同样发现奖赏加工任务中，物质成瘾者和行为成瘾者在背外侧纹状体(如壳核和尾状核)激活增加，特别是结果发现物质成瘾个体多巴胺合成核团黑质的激活增加。虽然物质成瘾者和行为成瘾者联合分析未发现重叠激活脑区，但行为成瘾者在奖赏加工任务中也激活了背外侧纹状体(如壳核、尾状核等)。背外侧纹状体分为背内侧部分(尾状核, caudate)和背外侧部分(壳核, putamen)，其中尾状核主要接收来自背外侧前额叶皮层的投射，壳核主要接收来自感觉核运动皮层的投射。最近，研究者将习惯和动机联系到一起，他们将新纹状体-习惯理论的最新版本增加了一个假设，即迁移到背侧纹状体的控制使习惯性行为具有"must do"的动机驱动(Brand, 2022)，这实质上为习惯增加了一个强大的动机成分。反过来，这种动机理论解释为什么习惯性行为"must do"。有证据表明，背侧纹状体除了运动和习惯功能外，还参与动机功能，包括奖励刺激凸显或"want"的放大(Brand, 2022)。动机增加了成瘾行为"must do"，为解释转移回动机功能的性质提供了视角，了解它是如何被成瘾放大的，提供了神经理论支持。因此，在奖赏系统的动机驱动下，物质成瘾者和行为成瘾者会表现出对成瘾相关信息的接近偏向。从物质成瘾者壳核激活增加大于行为成瘾者来看，物质成瘾者在奖赏相关任务中会表现出更强的奖赏敏感性。

4.2 物质成瘾者和行为成瘾者不同任务综合变化

物质成瘾者和行为成瘾者在冲动系统均存在异常激活，而两者在反思系统上存在分离。Brand(2022)提出的模型(如图 1 所示)，将成瘾分为前期和后期。前期的"feels better"环路主要通过腹侧被盖区到达付隔核，最终投射到腹内侧前额叶皮质。后期的"must do"环路主要通过黑质影响壳核和尾状核最终投射到背外侧前额叶皮层。综合元分析结果，当前研究发现在奖赏任务上物质成瘾者和行为成瘾者均存在后期"must do"环路上的尾状核、壳核异常。但对比分析发现相对于行为成瘾者，物质成瘾者在奖赏加工任务中壳核激活更高，说明物质成瘾者可能存在更强的奖赏敏感性。同样，在成瘾物线索渴求诱导任务中，物质成瘾者和行为成瘾者布罗德曼 9 区即背外侧前额叶皮层激活均增加。该结果支持了物质成瘾者和行为成瘾者后期"must do"环路中背外侧前额叶皮层异常。具体而言，额下回与抑制控制和注意控制存在联系。物质成瘾者和行为成瘾者额下回激活的增加，说明在面对成瘾刺激物时，成瘾者表现出更强注意模式(Hampshire er al., 2010)。但是，在抑制控制中物质成瘾背外侧前额叶皮层激活显著降低，而行为成瘾背外侧前额叶皮层激活增加。额中回即背外侧

前额叶皮层，涉及认知控制，包括工作记忆更新、注意力控制和动机/情绪调节。物质成瘾者额中回激活的降低可能会削弱其抑制控制自上而下的调节，导致成瘾的加深和维持(Le et al, 2021)。而行为成瘾者额中回激活增加可能是通过补偿性的激活以满足任务要求。

综上，在线索渴求诱导任务中，行为成瘾者和物质成瘾者背外侧前额叶皮层激活均增加。在抑制控制任务中，物质成瘾者背外侧前额叶皮层激活降低；行为成瘾者背外侧前额叶皮层激活增加，能通过补偿性的激活以满足任务要求。物质成瘾者后期的"must do"环路均存在异常，即物质成瘾损伤了个体抑制控制和奖赏加工能力，相对的行为成瘾者仅在奖赏加工环路上表现出异常。因此，行为成瘾者可能保留了一定的抑制控制能力。

4.3 研究局限

本研究虽然收集了所有 fMRI 的物质成瘾和行为成瘾文献，并根据任务进行了基于全脑的元分析，但还存在几个缺点。首先，研究任务仅仅局限于抑制控制、线索渴求诱导和奖赏加工，其他磁共振任务态研究由于数量有限，未能纳入研究。因此，进一步研究还需要纳入更多不同任务态文章，分析物质成瘾者和行为成瘾者脑激活模式特异性和相似性变化。其次，在物质成瘾者和行为成瘾者中男女比例并不平衡，特别是行为成瘾中男性数量远远多于女性。因此，进一步研究应该更多探究女性在物质成瘾和行为成瘾后脑激活模式的变化。最后，研究仅仅纳入了磁共振任务态文章，而基于其他模态的研究被排除在外。进一步研究应该扩大文献范围，探究不同模态下物质成瘾者和行为成瘾者脑激活模式的特异性和相似性，如静息态、结构像、功能连接等。

5 结论

结果表明物质成瘾者和行为成瘾者在纹状体-前额叶的激活模式可能存在重合和分离。在奖赏加工相关任务中，物质成瘾者和行为成瘾者额下回均表现出异常激活增加，物质成瘾者纹状体激活强于行为成瘾者，说明物质成瘾者和行为成瘾者在冲动系统均有异常，但是物质成瘾者的损伤程度可能更强；在抑制控制相关任务中，物质成瘾者背外侧前额皮层激活降低，行为成瘾者背外侧前额叶皮层激活增加，说明物质成瘾者反思系统受损，而行为成瘾者在反思系统上可能存在补偿性机制。

参考文献

Albein‐Urios, N., Verdejo‐Román, J., Asensio, S., Soriano‐Mas, C., Martínez‐González, J. M., & Verdejo‐García, A. (2014). Re‐appraisal of negative emotions in cocaine dependence: Dysfunctional corticolimbic activation and connectivity. *Addiction Biology*, *19*(3), 415–426. https://doi.org/10.1111/j.1369-1600.2012.00497.x

Balodis, I. M., Kober, H., Worhunsky, P. D., Stevens, M. C., Pearlson, G. D., & Potenza, M. N. (2012). Diminished frontostriatal activity during processing of monetary rewards and losses in pathological gambling. *Biological Psychiatry*, *71*(8), 749–757. https://doi.org/10.1016/j.biopsych.2012.01.006

Blaine, S. K., Wemm, S., Fogelman, N., Lacadie, C., Seo, D., Scheinost, D., & Sinha, R. (2020). Association of Prefrontal-Striatal Functional Pathology With Alcohol Abstinence Days at Treatment Initiation and Heavy Drinking After Treatment Initiation. *The American Journal of Psychiatry*, *177*(11), 1048–1059. https://doi.org/10.1176/appi.ajp.2020.19070703

Brand, M. (2022). Can internet use become addictive? *Science*, *376*(6595), 798–799. https://doi.org/10.1126/science.abn4189

Brand, M., Wegmann, E., Stark, R., Müller, A., Wölfling, K., Robbins, T. W., & Potenza, M. N. (2019). The Interaction of Person-Affect-Cognition-Execution (I-PACE) model for addictive behaviors: Update, generalization to addictive behaviors beyond internet-use disorders, and specification of the process character of addictive behaviors. *Neuroscience & Biobehavioral Reviews*, *104*, 1–10. https://doi.org/10.1016/j.neubiorev.2019.06.032

Ceceli, A. O., Huang, Y., Gaudreault, P.-O., McClain, N. E., King, S. G., Kronberg, G., Brackett, A., Hoberman, G. N., Gray, J. H., Garland, E. L., Alia-Klein, N., & Goldstein, R. Z. (2023). Recovery of inhibitory control prefrontal cortex function in inpatients with heroin use disorder: A 15-week longitudinal fMRI study. *medRxiv*, 2023.03.28.23287864. https://doi.org/10.1101/2023.03.28.23287864

Ceceli, A. O., King, S. G., McClain, N., Alia-Klein, N., & Goldstein, R. Z. (2023). The Neural Signature of Impaired Inhibitory Control in Individuals with Heroin Use Disorder. *The Journal of Neuroscience*, *43*(1), 173–182. https://doi.org/10.1523/JNEUROSCI.1237-

22.2022

Ceceli, A. O., Parvaz, M. A., King, S., Schafer, M., Malaker, P., Sharma, A., Alia-Klein, N., & Goldstein, R. Z. (2023). Altered prefrontal signaling during inhibitory control in a salient drug context in cocaine use disorder. *Cerebral Cortex (New York, N.Y.: 1991)*, *33*(3), 597–611. https://doi.org/10.1093/cercor/bhac087

Chen, M., Sun, Y., Lu, L., & Shi, J. (2017). Similarities and Differences in Neurobiology. *Advances in Experimental Medicine and Biology*, *1010*, 45–58. https://doi.org/10.1007/978-981-10-5562-1_3

Choi, J.-S., Shin, Y.-C., Jung, W. H., Jang, J. H., Kang, D.-H., Choi, C.-H., Choi, S.-W., Lee, J.-Y., Hwang, J. Y., & Kwon, J. S. (2012). Altered brain activity during reward anticipation in pathological gambling and obsessive-compulsive disorder. *PloS One*, *7*(9), e45938. https://doi.org/10.1371/journal.pone.0045938

Criaud, M., & Boulinguez, P. (2013). Have we been asking the right questions when assessing response inhibition in go/no-go tasks with fMRI? A meta-analysis and critical review. *Neuroscience and Biobehavioral Reviews*, *37*(1), 11–23. https://doi.org/10.1016/j.neubiorev.2012.11.003

Crockford, D. N., Goodyear, B., Edwards, J., Quickfall, J., & el-Guebaly, N. (2005). Cue-induced brain activity in pathological gamblers. *Biological Psychiatry*, *58*(10), 787–795. https://doi.org/10.1016/j.biopsych.2005.04.037

Cyr, M., Tau, G. Z., Fontaine, M., Levin, F. R., & Marsh, R. (2019). Deficient Functioning of Frontostriatal Circuits During the Resolution of Cognitive Conflict in Cannabis-Using Youth. *Journal of the American Academy of Child and Adolescent Psychiatry*, *58*(7), 702–711. https://doi.org/10.1016/j.jaac.2018.09.436

Czapla, M., Baeuchl, C., Simon, J. J., Richter, B., Kluge, M., Friederich, H.-C., Mann, K., Herpertz, S. C., & Loeber, S. (2017). Do alcohol-dependent patients show different neural activation during response inhibition than healthy controls in an alcohol-related fMRI go/no-go-task? *Psychopharmacology*, *234*(6), 1001–1015. https://doi.org/10.1007/s00213-017-4541-9

Dakhili, A., Sangchooli, A., Jafakesh, S., Zare-Bidoky, M., Soleimani, G., Batouli, S. A. H., Kazemi, K., Faghiri, A., Oghabian, M. A., & Ekhtiari, H. (2022). Cue-induced craving

and negative emotion disrupt response inhibition in methamphetamine use disorder: Behavioral and fMRI results from a mixed Go/No-Go task. *Drug and Alcohol Dependence*, *233*, 109353. https://doi.org/10.1016/j.drugalcdep.2022.109353

Dennis, L. E., Kohno, M., McCready, H. D., Schwartz, D. L., Schwartz, B., Lahna, D., Nagel, B. J., Mitchell, S. H., & Hoffman, W. F. (2020). Neural correlates of reward magnitude and delay during a probabilistic delay discounting task in alcohol use disorder. *Psychopharmacology*, *237*(1), 263–278. https://doi.org/10.1007/s00213-019-05364-3

Ding, W., Sun, J., Sun, Y.-W., Chen, X., Zhou, Y., Zhuang, Z., Li, L., Zhang, Y., Xu, J., & Du, Y. (2014). Trait impulsivity and impaired prefrontal impulse inhibition function in adolescents with internet gaming addiction revealed by a Go/No-Go fMRI study. *Behavioral and Brain Functions: BBF*, *10*, 20. https://doi.org/10.1186/1744-9081-10-20

Ding, W. M., Sun, J. H., Sun, Y. W., Li, L., Zhou, Y., Du, Y. S., & Xu, J. R. (2013). The fMRI Study of Reward System in Adolescents with Internet Gaming Addiction. *Journal of Clinical Radiology, 32*(9), 1226-1229. https://doi.org/10.13437/j.cnki.jcr.2013.09.003

[丁伟娜, 孙锦华, 孙雅文, 李磊, 周滟, 杜亚松, & 许建荣. (2013). 青少年网络游戏成瘾奖赏系统的 fMRI 研究. *临床放射学杂志*, *32*(9), 1226–1229. https://doi.org/10.13437/j.cnki.jcr.2013.09.003]

Dong, G., Devito, E. E., Du, X., & Cui, Z. (2012). Impaired inhibitory control in 《internet addiction disorder》: A functional magnetic resonance imaging study. *Psychiatry Research*, *203*(2–3), 153–158. https://doi.org/10.1016/j.pscychresns.2012.02.001

Dong, G., Hu, Y., & Lin, X. (2013). Reward/punishment sensitivities among internet addicts: Implications for their addictive behaviors. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *46*, 139–145. https://doi.org/10.1016/j.pnpbp.2013.07.007

Dong, G., Hu, Y., Lin, X., & Lu, Q. (2013). What makes Internet addicts continue playing online even when faced by severe negative consequences? Possible explanations from an fMRI study. *Biological Psychology*, *94*(2), 282–289. https://doi.org/10.1016/j.biopsycho.2013.07.009

Dong, G., Huang, J., & Du, X. (2011). Enhanced reward sensitivity and decreased loss sensitivity in Internet addicts: An fMRI study during a guessing task. *Journal of Psychiatric Research*, *45*(11), 1525–1529. https://doi.org/10.1016/j.jpsychires.2011.06.017

Dong, G., Li, H., Wang, L., & Potenza, M. N. (2017). Cognitive control and reward/loss processing in Internet gaming disorder: Results from a comparison with recreational Internet game-users. *European Psychiatry*, *44*, 30–38. https://doi.org/10.1016/j.eurpsy.2017.03.004

Dong, G., Shen, Y., Huang, J., & Du, X. (2013). Impaired error-monitoring function in people with Internet addiction disorder: An event-related fMRI study. *European Addiction Research*, *19*(5), 269–275. https://doi.org/10.1159/000346783

Filbey, F. M., Dunlop, J., & Myers, U. S. (2013). Neural effects of positive and negative incentives during marijuana withdrawal. *PloS One*, *8*(5), e61470. https://doi.org/10.1371/journal.pone.0061470

Fu, L., Bi, G., Zou, Z., Wang, Y., Ye, E., Ma, L., Ming-Fan, null, & Yang, Z. (2008). Impaired response inhibition function in abstinent heroin dependents: An fMRI study. *Neuroscience Letters*, *438*(3), 322–326. https://doi.org/10.1016/j.neulet.2008.04.033

Fu, L. P., Bi, G. H., Wang, Y., Zou, S, T., Shao, Y. C., Ye, E. M., Fan, M., Ma, L., & Yang, Z., (2008). Impaired cognitive function in abstinent heroin addiction: an functional magnetic resonance imaging study. *Chin J Psychiatry, 41*(3), 136–139

[富丽萍, 毕国华, 王岩, 邹智彤, 邵永聪, 叶恩茂, 范明, 马林, & 杨征. (2008). 戒断期海洛因依赖者额叶认知功能的功能磁共振成像研究. *中国精神科杂志, 41*(3), 136–139]

Gelskov, S. V., Madsen, K. H., Ramsøy, T. Z., & Siebner, H. R. (2016). Aberrant neural signatures of decision-making: Pathological gamblers display cortico-striatal hypersensitivity to extreme gambles. *NeuroImage*, *128*, 342–352. https://doi.org/10.1016/j.neuroimage.2016.01.002

Gerhardt, S., Luderer, M., Bumb, J. M., Sobanski, E., Moggi, F., Kiefer, F., & Vollstädt-Klein, S. (2021). Stop What You're Doing!-An fMRI Study on Comparisons of Neural Subprocesses of Response Inhibition in ADHD and Alcohol Use Disorder. *Frontiers in Psychiatry*, *12*, 691930. https://doi.org/10.3389/fpsyt.2021.691930

Gilman, J. M., & Hommer, D. W. (2008). Modulation of brain response to emotional images by alcohol cues in alcohol-dependent patients. *Addiction Biology*, *13*(3–4), 423–434. https://doi.org/10.1111/j.1369-1600.2008.00111.x

Gilman, J. M., Smith, A. R., Bjork, J. M., Ramchandani, V. A., Momenan, R., & Hommer, D. W.

(2015). Cumulative gains enhance striatal response to reward opportunities in alcohol-dependent patients. *Addiction Biology*, *20*(3), 580–593. https://doi.org/10.1111/adb.12147

Goldstein, R. Z., Alia-Klein, N., Tomasi, D., Zhang, L., Cottone, L. A., Maloney, T., Telang, F., Caparelli, E. C., Chang, L., Ernst, T., Samaras, D., Squires, N. K., & Volkow, N. D. (2007). Is decreased prefrontal cortical sensitivity to monetary reward associated with impaired motivation and self-control in cocaine addiction? *The American Journal of Psychiatry*, *164*(1), 43–51. https://doi.org/10.1176/ajp.2007.164.1.43

Goudriaan, A. E., de Ruiter, M. B., van den Brink, W., Oosterlaan, J., & Veltman, D. J. (2010). Brain activation patterns associated with cue reactivity and craving in abstinent problem gamblers, heavy smokers and healthy controls: An fMRI study. *Addiction Biology*, *15*(4), 491–503. https://doi.org/10.1111/j.1369-1600.2010.00242.x

Grodin, E. N., Steckler, L. E., & Momenan, R. (2016). Altered Striatal Response During Effort-Based Valuation and Motivation in Alcohol-Dependent Individuals. *Alcohol and Alcoholism (Oxford, Oxfordshire)*, *51*(6), 638–646. https://doi.org/10.1093/alcalc/agw003

Hampshire, A., Chamberlain, S. R., Monti, M. M., Duncan, J., & Owen, A. M. (2010). The role of the right inferior frontal gyrus: Inhibition and attentional control. *NeuroImage*, *50*(3), 1313–1319. https://doi.org/10.1016/j.neuroimage.2009.12.109

Hannah, R., & Aron, A. R. (2021). Towards real-world generalizability of a circuit for action-stopping. *Nature Reviews. Neuroscience*, *22*(9), 538–552. https://doi.org/10.1038/s41583-021-00485-1

He, J. B., Nie, Y. F., Zhou, Z. K., & Chai, Y. (2017). Are both neural mechanisms of Internet gaming and heroin addicts the same? Research evidence based on MRI. *Advances in Psychological Science*, *25*(8), 1327. https://doi.org/10.3724/SP.J.1042.2017.01327

[贺金波, 聂余峰, 周宗奎, & 柴瑶. (2017). 网络游戏成瘾与海洛因成瘾存在相同的神经机制吗？——基于MRI的证据. *心理科学进展*. *25*(8), 1327. https://doi.org/10.3724/SP.J.1042.2017.01327]

Heinz, A., Wrase, J., Kahnt, T., Beck, A., Bromand, Z., Grüsser, S. M., Kienast, T., Smolka, M. N., Flor, H., & Mann, K. (2007). Brain activation elicited by affectively positive stimuli is associated with a lower risk of relapse in detoxified alcoholic subjects. *Alcoholism, Clinical and Experimental Research*, *31*(7), 1138–1147. https://doi.org/10.1111/j.1530-

0277.2007.00406.x

Hong, J. S., Kim, S. M., Jung, H. Y., Kang, K. D., Min, K. J., & Han, D. H. (2017). Cognitive avoidance and aversive cues related to tobacco in male smokers. *Addictive Behaviors*, *73*, 158–164. https://doi.org/10.1016/j.addbeh.2017.05.003

Hu, C. P., Di, X., Li, J. W., Sui, J., & Peng, K. P. (2015). Meta-analysis of Neuroimaging Studies. *Advances in Psychological Science. 23*(7), 1118-1129.

[胡传鹏, 邸新, 李佳蔚, 隋洁, & 彭凯平. (2015). 神经成像数据的元分析. *心理科学进展, 23*(07), 1118–1129.]

Huang, S., Zhang, Z., Dai, Y., Zhang, C., Yang, C., Fan, L., Liu, J., Hao, W., & Chen, H. (2018). Craving Responses to Methamphetamine and Sexual Visual Cues in Individuals With Methamphetamine Use Disorder After Long-Term Drug Rehabilitation. *Frontiers in Psychiatry*, *9*, 145. https://doi.org/10.3389/fpsyt.2018.00145

Huang, Y., Ceceli, A. O., Kronberg, G., King, S., Malaker, P., Parvaz, M. A., Alia-Klein, N., Garland, E. L., & Goldstein, R. Z. (2023). Association of Cortico-Striatal Engagement During Cue Reactivity, Reappraisal, and Savoring of Drug and Non-Drug Stimuli With Craving in Heroin Addiction. *American Journal of Psychiatry*, appi.ajp.20220759. https://doi.org/10.1176/appi.ajp.20220759

Jan, R. K., Lin, J. C., McLaren, D. G., Kirk, I. J., Kydd, R. R., & Russell, B. R. (2014). The Effects of Methylphenidate on Cognitive Control in Active Methamphetamine Dependence Using Functional Magnetic Resonance Imaging. *Frontiers in Psychiatry*, *5*, 20. https://doi.org/10.3389/fpsyt.2014.00020

Jia, Z., Worhunsky, P. D., Carroll, K. M., Rounsaville, B. J., Stevens, M. C., Pearlson, G. D., & Potenza, M. N. (2011). An initial study of neural responses to monetary incentives as related to treatment outcome in cocaine dependence. *Biological Psychiatry*, *70*(6), 553–560. https://doi.org/10.1016/j.biopsych.2011.05.008

Kim, J., Kim, H., & Kang, E. (2017). Impaired Feedback Processing for Symbolic Reward in Individuals with Internet Game Overuse. *Frontiers in Psychiatry*, *8*, 195. https://doi.org/10.3389/fpsyt.2017.00195

Kim, J.-E., Son, J.-W., Choi, W.-H., Kim, Y.-R., Oh, J.-H., Lee, S., & Kim, J.-K. (2014). Neural responses to various rewards and feedback in the brains of adolescent Internet addicts

detected by functional magnetic resonance imaging. *Psychiatry and Clinical Neurosciences*, *68*(6), 463–470. https://doi.org/10.1111/pcn.12154

Ko, C.-H., Hsieh, T.-J., Chen, C.-Y., Yen, C.-F., Chen, C.-S., Yen, J.-Y., Wang, P.-W., & Liu, G.-C. (2014). Altered brain activation during response inhibition and error processing in subjects with Internet gaming disorder: A functional magnetic imaging study. *European Archives of Psychiatry and Clinical Neuroscience*, *264*(8), 661–672. https://doi.org/10.1007/s00406-013-0483-3

Ko, C.-H., Liu, G.-C., Hsiao, S., Yen, J.-Y., Yang, M.-J., Lin, W.-C., Yen, C.-F., & Chen, C.-S. (2009). Brain activities associated with gaming urge of online gaming addiction. *Journal of Psychiatric Research*, *43*(7), 739–747. https://doi.org/10.1016/j.jpsychires.2008.09.012

Ko, C.-H., Liu, G.-C., Yen, J.-Y., Chen, C.-Y., Yen, C.-F., & Chen, C.-S. (2013). Brain correlates of craving for online gaming under cue exposure in subjects with Internet gaming addiction and in remitted subjects. *Addiction Biology*, *18*(3), 559–569. https://doi.org/10.1111/j.1369-1600.2011.00405.x

Kober, H., DeVito, E. E., DeLeone, C. M., Carroll, K. M., & Potenza, M. N. (2014). Cannabis abstinence during treatment and one-year follow-up: Relationship to neural activity in men. *Neuropsychopharmacology*, *39*(10), 2288–2298. https://doi.org/10.1038/npp.2014.82

Kober, H., Lacadie, C. M., Wexler, B. E., Malison, R. T., Sinha, R., & Potenza, M. N. (2016). Brain Activity During Cocaine Craving and Gambling Urges: An fMRI Study. *Neuropsychopharmacology*, *41*(2), 628–637. https://doi.org/10.1038/npp.2015.193

Le, T. M., Potvin, S., Zhornitsky, S., & Li, C.-S. R. (2021). Distinct patterns of prefrontal cortical disengagement during inhibitory control in addiction: A meta-analysis based on population characteristics. *Neuroscience & Biobehavioral Reviews*, *127*, 255–269. https://doi.org/10.1016/j.neubiorev.2021.04.028

Lee, J., Lee, S., Chun, J. W., Cho, H., Kim, D., & Jung, Y.-C. (2015). Compromised Prefrontal Cognitive Control Over Emotional Interference in Adolescents with Internet Gaming Disorder. *Cyberpsychology, Behavior and Social Networking*, *18*(11), 661–668. https://doi.org/10.1089/cyber.2015.0231

Lei, W., Liu, K., Chen, G., Tolomeo, S., Liu, C., Peng, Z., Liu, B., Liang, X., Huang, C., Xiang, B.,

Zhou, J., Zhao, F., Yu, R., & Chen, J. (2022). Blunted reward prediction error signals in internet gaming disorder. *Psychological Medicine*, *52*(11), 2124–2133. https://doi.org/10.1017/S003329172000402X

Li, C. R., Huang, C., Yan, P., Bhagwagar, Z., Milivojevic, V., & Sinha, R. (2008). Neural correlates of impulse control during stop signal inhibition in cocaine-dependent men. *Neuropsychopharmacology*, *33*(8), 1798–1806. https://doi.org/10.1038/sj.npp.1301568

Li, C.-S. R., Luo, X., Yan, P., Bergquist, K., & Sinha, R. (2009). Altered impulse control in alcohol dependence: Neural measures of stop signal performance. *Alcoholism, Clinical and Experimental Research*, *33*(4), 740–750. https://doi.org/10.1111/j.1530-0277.2008.00891.x

Li, Q., Wang, Y., Zhang, Y., Li, W., Yang, W., Zhu, J., Wu, N., Chang, H., Zheng, Y., Qin, W., Zhao, L., Yuan, K., Liu, J., Wang, W., & Tian, J. (2012). Craving correlates with mesolimbic responses to heroin-related cues in short-term abstinence from heroin: An event-related fMRI study. *Brain Research*, *1469*, 63–72. https://doi.org/10.1016/j.brainres.2012.06.024

Li, Q.， Wang, Y. R.， Li, W.， Yang, W. C., Zhu, J., Zhang, Y., Chan, J., & Wang, W． (2013). fMRI Study on Craving and Brain Response to Heroin Related Clues in Heroin Dependent Patients During Long Term Abstinence. *Journal of Clinical Radiology, 32*(3), 313-316. https://doi.org/10.13437/j.cnki.jcr.2013.03.036

[李强, 王亚蓉, 李玮, 杨伟川, 朱佳, 郑颖, 陈佳杰, & 王玮. (2013). 长期强制戒断的海洛因依赖者对毒品线索反应的 fMRI 研究. *临床放射学杂志*, *32*(3), 313–316. https://doi.org/10.13437/j.cnki.jcr.2013.03.036]

Limbrick-Oldfield, E. H., Mick, I., Cocks, R. E., McGonigle, J., Sharman, S. P., Goldstone, A. P., Stokes, P. R. A., Waldman, A., Erritzoe, D., Bowden-Jones, H., Nutt, D., Lingford-Hughes, A., & Clark, L. (2017). Neural substrates of cue reactivity and craving in gambling disorder. *Translational Psychiatry*, *7*(1), e992. https://doi.org/10.1038/tp.2016.256

Liu, G.-C., Yen, J.-Y., Chen, C.-Y., Yen, C.-F., Chen, C.-S., Lin, W.-C., & Ko, C.-H. (2014). Brain activation for response inhibition under gaming cue distraction in internet gaming disorder. *The Kaohsiung Journal of Medical Sciences*, *30*(1), 43–51.

https://doi.org/10.1016/j.kjms.2013.08.005

Liu, J., Li, W., Zhou, S., Zhang, L., Wang, Z., Zhang, Y., Jiang, Y., & Li, L. (2016). Functional characteristics of the brain in college students with internet gaming disorder. *Brain Imaging and Behavior*, *10*(1), 60–67. https://doi.org/10.1007/s11682-015-9364-x

Liu, J. C., Ran, G. M., & Zhang, Q. (2022). The neural activities of different emotion carriers and their similarities and differences: A meta-analysis of functional neuroimaging studies. *Advances in Psychological Science,* *30*(3), 536–555. https://doi.org/10.3724/SP.J.1042.2022.00536

[刘俊材, 冉光明, & 张琪. 不同情绪载体的神经活动及其异同 ——脑成像研究的 ALE 元分析. *心理科学进展*. *30*(3), 536–555. https://doi.org/10.3724/SP.J.1042.2022.00536]

Liu, L., Xue, G., Potenza, M. N., Zhang, J.-T., Yao, Y.-W., Xia, C.-C., Lan, J., Ma, S.-S., & Fang, X.-Y. (2017). Dissociable neural processes during risky decision-making in individuals with Internet-gaming disorder. *NeuroImage. Clinical*, *14*, 741–749. https://doi.org/10.1016/j.nicl.2017.03.010

Liu, L., Yip, S. W., Zhang, J.-T., Wang, L.-J., Shen, Z.-J., Liu, B., Ma, S.-S., Yao, Y.-W., & Fang, X.-Y. (2017). Activation of the ventral and dorsal striatum during cue reactivity in Internet gaming disorder. *Addiction Biology*, *22*(3), 791–801. https://doi.org/10.1111/adb.12338

Lorenz, R. C., Krüger, J.-K., Neumann, B., Schott, B. H., Kaufmann, C., Heinz, A., & Wüstenberg, T. (2013). Cue reactivity and its inhibition in pathological computer game players. *Addiction Biology*, *18*(1), 134–146. https://doi.org/10.1111/j.1369-1600.2012.00491.x

Luijten, M., Meerkerk, G.-J., Franken, I. H. A., van de Wetering, B. J. M., & Schoenmakers, T. M. (2015). An fMRI study of cognitive control in problem gamers. *Psychiatry Research*, *231*(3), 262–268. https://doi.org/10.1016/j.pscychresns.2015.01.004

Luijten, M., Schellekens, A. F., Kühn, S., Machielse, M. W. J., & Sescousse, G. (2017). Disruption of Reward Processing in Addiction: An Image-Based Meta-analysis of Functional Magnetic Resonance Imaging Studies. *JAMA Psychiatry*, *74*(4), 387–398. https://doi.org/10.1001/jamapsychiatry.2016.3084

Luo, S., Ainslie, G., Giragosian, L., & Monterosso, J. R. (2011). Striatal hyposensitivity to delayed rewards among cigarette smokers. *Drug and Alcohol Dependence*, *116*(1–3), 18–23.

https://doi.org/10.1016/j.drugalcdep.2010.11.012

Ma, L., Steinberg, J. L., Cunningham, K. A., Lane, S. D., Bjork, J. M., Neelakantan, H., Price, A. E., Narayana, P. A., Kosten, T. R., Bechara, A., & Moeller, F. G. (2015). Inhibitory behavioral control: A stochastic dynamic causal modeling study comparing cocaine dependent subjects and controls. *NeuroImage : Clinical*, *7*, 837–847. https://doi.org/10.1016/j.nicl.2015.03.015

Miedl, S. F., Peters, J., & Büchel, C. (2012). Altered neural reward representations in pathological gamblers revealed by delay and probability discounting. *Archives of General Psychiatry*, *69*(2), 177–186. https://doi.org/10.1001/archgenpsychiatry.2011.1552

Miedl, S. F., Wiswede, D., Marco-Pallarés, J., Ye, Z., Fehr, T., Herrmann, M., & Münte, T. F. (2015). The neural basis of impulsive discounting in pathological gamblers. *Brain Imaging and Behavior*, *9*(4), 887–898. https://doi.org/10.1007/s11682-015-9352-1

Moeller, S. J., Tomasi, D., Honorio, J., Volkow, N. D., & Goldstein, R. Z. (2012). Dopaminergic involvement during mental fatigue in health and cocaine addiction. *Translational Psychiatry*, *2*(10), e176. https://doi.org/10.1038/tp.2012.110

Moeller, S. J., Zilverstand, A., Konova, A. B., Kundu, P., Parvaz, M. A., Preston-Campbell, R., Bachi, K., Alia-Klein, N., & Goldstein, R. Z. (2018). Neural Correlates of Drug-Biased Choice in Currently Using and Abstinent Individuals With Cocaine Use Disorder. *Biological Psychiatry. Cognitive Neuroscience and Neuroimaging*, *3*(5), 485–494. https://doi.org/10.1016/j.bpsc.2017.11.001

Monterosso, J. R., Ainslie, G., Xu, J., Cordova, X., Domier, C. P., & London, E. D. (2007). Frontoparietal cortical activity of methamphetamine-dependent and comparison subjects performing a delay discounting task. *Human Brain Mapping*, *28*(5), 383–393. https://doi.org/10.1002/hbm.20281

Müller-Oehring, E. M., Le Berre, A.-P., Serventi, M., Kalon, E., Haas, A. L., Padula, C. B., & Schulte, T. (2019). Brain activation to cannabis- and alcohol-related words in alcohol use disorder. *Psychiatry Research. Neuroimaging*, *294*, 111005. https://doi.org/10.1016/j.pscychresns.2019.111005

Navas, J. F., Contreras-Rodríguez, O., Verdejo-Román, J., Perandrés-Gómez, A., Albein-Urios, N., Verdejo-García, A., & Perales, J. C. (2017). Trait and neurobiological underpinnings of

negative emotion regulation in gambling disorder. *Addiction (Abingdon, England)*, *112*(6), 1086–1094. https://doi.org/10.1111/add.13751

Nestor, L. J., Ghahremani, D. G., Monterosso, J., & London, E. D. (2011). Prefrontal hypoactivation during cognitive control in early abstinent methamphetamine-dependent subjects. *Psychiatry Research*, *194*(3), 287–295. https://doi.org/10.1016/j.pscychresns.2011.04.010

Noel, X., Brevers, D., & Bechara, A. (2013). A neurocognitive approach to understanding the neurobiology of addiction. *CURRENT OPINION IN NEUROBIOLOGY*, *23*(4), 632–638. https://doi.org/10.1016/j.conb.2013.01.018

Pelliccia, V., Del Vecchio, M., Avanzini, P., Revay, M., Sartori, I., & Caruana, F. (2023). 70 Years of Human Cingulate Cortex Stimulation. Functions and Dysfunctions Through the Lens of Electrical Stimulation. *Journal of Clinical Neurophysiology*, *40*(6), 491. https://doi.org/10.1097/WNP.0000000000000961

Picó-Pérez, M., Costumero, V., Verdejo-Román, J., Albein-Urios, N., Martínez-González, J. M., Soriano-Mas, C., Barrós-Loscertales, A., & Verdejo-Garcia, A. (2022). Brain networks alterations in cocaine use and gambling disorders during emotion regulation. *Journal of Behavioral Addictions*, *11*(2), 373–385. https://doi.org/10.1556/2006.2022.00018

Power, Y., Goodyear, B., & Crockford, D. (2012). Neural correlates of pathological gamblers preference for immediate rewards during the iowa gambling task: An fMRI study. *Journal of Gambling Studies*, *28*(4), 623–636. https://doi.org/10.1007/s10899-011-9278-5

Qiu, Z., & Wang, J. (2021). Altered neural activities during response inhibition in adults with addiction: A voxel-wise meta-analysis. *Psychological Medicine*, *51*(3), 387–399. https://doi.org/10.1017/S0033291721000362

Robinson, T., & Berridge, K. (1993). The neural basis of drug craving: An incentive-sensitization theory of addiction. *Brain Research Reviews*, *18*(3). https://doi.org/10.1016/0165-0173(93)90013-p

Rolls, E. T. (2019). The cingulate cortex and limbic systems for emotion, action, and memory. *Brain Structure & Function*, *224*(9), 3001–3018. https://doi.org/10.1007/s00429-019-01945-2

Romanczuk-Seiferth, N., Koehler, S., Dreesen, C., Wüstenberg, T., & Heinz, A. (2015).

Pathological gambling and alcohol dependence: Neural disturbances in reward and loss avoidance processing. *Addiction Biology*, *20*(3), 557–569. https://doi.org/10.1111/adb.12144

Schmidt, C., Gleesborg, C., Schmidt, H., Kvamme, T. L., Lund, T. E., Voon, V., & Møller, A. (2021). A bias towards natural rewards away from gambling cues in gamblers undergoing active treatment. *Brain Research*, *1764*, 147479. https://doi.org/10.1016/j.brainres.2021.147479

Schulte, T., Jung, Y.-C., Sullivan, E. V., Pfefferbaum, A., Serventi, M., & Müller-Oehring, E. M. (2017). The neural correlates of priming emotion and reward systems for conflict processing in alcoholics. *Brain Imaging and Behavior*, *11*(6), 1751–1768. https://doi.org/10.1007/s11682-016-9651-1

Schulte, T., Müller-Oehring, E. M., Sullivan, E. V., & Pfefferbaum, A. (2012). Synchrony of corticostriatal-midbrain activation enables normal inhibitory control and conflict processing in recovering alcoholic men. *Biological Psychiatry*, *71*(3), 269–278. https://doi.org/10.1016/j.biopsych.2011.10.022

Seo, D., Lacadie, C. M., & Sinha, R. (2016). Neural Correlates and Connectivity Underlying Stress-Related Impulse Control Difficulties in Alcoholism. *Alcoholism, Clinical and Experimental Research*, *40*(9), 1884–1894. https://doi.org/10.1111/acer.13166

Seok, J.-W., Lee, K. H., Sohn, S., & Sohn, J.-H. (2015). Neural substrates of risky decision making in individuals with Internet addiction. *The Australian and New Zealand Journal of Psychiatry*, *49*(10), 923–932. https://doi.org/10.1177/0004867415598009

Sescousse, G., Barbalat, G., Domenech, P., & Dreher, J.-C. (2013). Imbalance in the sensitivity to different types of rewards in pathological gambling. *Brain: A Journal of Neurology*, *136*(Pt 8), 2527–2538. https://doi.org/10.1093/brain/awt126

Shen, X., Li, Z., Sheng, J., Zhou, X., & Wang, J. (2023). Functional MRI of inhibitory control processing in problematic mobile video gamers. *Psychiatry Research*, *325*, 115220. https://doi.org/10.1016/j.psychres.2023.115220

Sjoerds, Z., van den Brink, W., Beekman, A. T. F., Penninx, B. W. J. H., & Veltman, D. J. (2014). Cue reactivity is associated with duration and severity of alcohol dependence: An FMRI study. *PloS One*, *9*(1), e84560. https://doi.org/10.1371/journal.pone.0084560

Stein, M., Steiner, L., Fey, W., Conring, F., Rieger, K., Federspiel, A., & Moggi, F. (2021). Alcohol-related context modulates neural correlates of inhibitory control in alcohol dependent patients: Preliminary data from an fMRI study using an alcohol-related Go/NoGo-task. *Behavioural Brain Research*, *398*, 112973. https://doi.org/10.1016/j.bbr.2020.112973

Sun, Y., Ying, H., Seetohul, R. M., Xuemei, W., Ya, Z., Qian, L., Guoqing, X., & Ye, S. (2012). Brain fMRI study of crave induced by cue pictures in online game addicts (male adolescents). *Behavioural Brain Research*, *233*(2), 563–576. https://doi.org/10.1016/j.bbr.2012.05.005

Tapert, S. F., Cheung, E. H., Brown, G. G., Frank, L. R., Paulus, M. P., Schweinsburg, A. D., Meloy, M. J., & Brown, S. A. (2003). Neural response to alcohol stimuli in adolescents with alcohol use disorder. *Archives of General Psychiatry*, *60*(7), 727–735. https://doi.org/10.1001/archpsyc.60.7.727

Teicher, M. H., Samson, J. A., Anderson, C. M., & Ohashi, K. (2016). The effects of childhood maltreatment on brain structure, function and connectivity. *Nature Reviews Neuroscience*, *17*(10), 652–666. https://doi.org/10.1038/nrn.2016.111

Tolomeo, S., & Yu, R. (2022). Brain network dysfunctions in addiction: A meta-analysis of resting-state functional connectivity. *Translational Psychiatry*, *12*(1), 41. https://doi.org/10.1038/s41398-022-01792-6

Turel, O., & Qahri-Saremi, H. (2016). Problematic Use of Social Networking Sites: Antecedents and Consequence from a Dual-System Theory Perspective. *JOURNAL OF MANAGEMENT INFORMATION SYSTEMS*, *33*(4), 1087–1116. https://doi.org/10.1080/07421222.2016.1267529

Turkeltaub, P. E., Eden, G. F., Jones, K. M., & Zeffiro, T. A. (2002). Meta-Analysis of the Functional Neuroanatomy of Single-Word Reading: Method and Validation. *NeuroImage*, *16*(3, Part A), 765–780. https://doi.org/10.1006/nimg.2002.1131

Volkow, N. D., Chang, L., Wang, G. J., Fowler, J. S., Leonido-Yee, M., Franceschi, D., Sedler, M. J., Gatley, S. J., Hitzemann, R., Ding, Y. S., Logan, J., Wong, C., & Miller, E. N. (2001). Association of dopamine transporter reduction with psychomotor impairment in methamphetamine abusers. *The American Journal of Psychiatry*, *158*(3), 377–382.

https://doi.org/10.1176/appi.ajp.158.3.377

von Deneen, K. M., Hussain, H., Waheed, J., Xinwen, W., Yu, D., & Yuan, K. (2022). Comparison of frontostriatal circuits in adolescent nicotine addiction and internet gaming disorder. *Journal of Behavioral Addictions*, *11*(1), 26–39. https://doi.org/10.1556/2006.2021.00086

Wang, L., Wu, L., Wang, Y., Li, H., Liu, X., Du, X., & Dong, G. (2017). Altered Brain Activities Associated with Craving and Cue Reactivity in People with Internet Gaming Disorder: Evidence from the Comparison with Recreational Internet Game Users. *Frontiers in Psychology*, *8*, 1150. https://doi.org/10.3389/fpsyg.2017.01150

Wang, L., Yang, G., Zheng, Y., Li, Z., Qi, Y., Li, Q., & Liu, X. (2021). Enhanced neural responses in specific phases of reward processing in individuals with Internet gaming disorder. *Journal of Behavioral Addictions*, *10*(1), 99–111. https://doi.org/10.1556/2006.2021.00003

Wang, L., Yang, G., Zheng, Y., Li, Z., Wei, P., Li, Q., Hu, K., & Liu, X. (2021). Neural substrates of deficient cognitive control in individuals with severe internet gaming disorder. *NeuroImage. Clinical*, *32*, 102828. https://doi.org/10.1016/j.nicl.2021.102828

Wang, Y., Hu, Y., Xu, J., Zhou, H., Lin, X., Du, X., & Dong, G. (2017). Dysfunctional Prefrontal Function Is Associated with Impulsivity in People with Internet Gaming Disorder during a Delay Discounting Task. *Frontiers in Psychiatry*, *8*, 287. https://doi.org/10.3389/fpsyt.2017.00287

Wesley, M. J., Lohrenz, T., Koffarnus, M. N., McClure, S. M., De La Garza, R., Salas, R., Thompson-Lake, D. G. Y., Newton, T. F., Bickel, W. K., & Montague, P. R. (2014). Choosing Money over Drugs: The Neural Underpinnings of Difficult Choice in Chronic Cocaine Users. *Journal of Addiction*, *2014*, 189853. https://doi.org/10.1155/2014/189853

Worhunsky, P. D., Malison, R. T., Rogers, R. D., & Potenza, M. N. (2014). Altered neural correlates of reward and loss processing during simulated slot-machine fMRI in pathological gambling and cocaine dependence. *Drug and Alcohol Dependence*, *145*, 77–86. https://doi.org/10.1016/j.drugalcdep.2014.09.013

Wrase, J., Schlagenhauf, F., Kienast, T., Wüstenberg, T., Bermpohl, F., Kahnt, T., Beck, A., Ströhle, A., Juckel, G., Knutson, B., & Heinz, A. (2007). Dysfunction of reward processing correlates with alcohol craving in detoxified alcoholics. *NeuroImage*, *35*(2), 787–794.

https://doi.org/10.1016/j.neuroimage.2006.11.043

Xiao, L., Hongli, Z., Guangheng, D., & Xiaoxia, D. (2015). Impaired risk evaluation in people with Internet gaming disorder: fMRI evidence from a probability discounting task. *Progress in Neuro-Psychopharmacology & Biological Psychiatry*, *56*. https://doi.org/10.1016/j.pnpbp.2014.08.016

Yan, W.-S., Chen, R.-T., Liu, M.-M., & Zheng, D.-H. (2021). Monetary Reward Discounting, Inhibitory Control, and Trait Impulsivity in Young Adults With Internet Gaming Disorder and Nicotine Dependence. *Frontiers in Psychiatry*, *12*, 628933. https://doi.org/10.3389/fpsyt.2021.628933

Yao, Y.-W., Liu, L., Ma, S.-S., Shi, X.-H., Zhou, N., Zhang, J.-T., & Potenza, M. N. (2017). Functional and structural neural alterations in Internet gaming disorder: A systematic review and meta-analysis. *Neuroscience & Biobehavioral Reviews*, *83*, 313–324. https://doi.org/10.1016/j.neubiorev.2017.10.029

Zeng, X., Han, X., Gao, F., Sun, Y., & Yuan, Z. (2023). Abnormal structural alterations and disrupted functional connectivity in behavioral addiction: A meta-analysis of VBM and fMRI studies. *Journal of Behavioral Addictions*, *12*(3), 599–612. https://doi.org/10.1556/2006.2023.00025

Zerekidze, A., Li, M., Javaheripour, N., Huff, L., Weiss, T., Walter, M., & Wagner, G. (2023). Neural Correlates of Impaired Cognitive Control in Individuals with Methamphetamine Dependence: An fMRI Study. *Brain Sciences*, *13*(2), 197. https://doi.org/10.3390/brainsci13020197

Zhang, J., Chen, S., Jiang, Q., Dong, H., Zhao, Z., Du, X., & Dong, G.-H. (2021). Disturbed craving regulation to gaming cues in internet gaming disorder: Implications for uncontrolled gaming behaviors. *Journal of Psychiatric Research*, *140*, 250–259. https://doi.org/10.1016/j.jpsychires.2021.05.051

Zhang, J., Dong, H., Zhao, Z., Chen, S., Jiang, Q., Du, X., & Dong, G.-H. (2020). Altered neural processing of negative stimuli in people with internet gaming disorder: fMRI evidence from the comparison with recreational game users. *Journal of Affective Disorders*, *264*, 324–332. https://doi.org/10.1016/j.jad.2020.01.008

Zhang, J., Hu, Y., Wang, Z., Wang, M., & Dong, G.-H. (2020). Males are more sensitive to reward

and less sensitive to loss than females among people with internet gaming disorder: fMRI evidence from a card-guessing task. *V*, *20*(1), 357. https://doi.org/10.1186/s12888-020-02771-1

Zhang, J.-T., Yao, Y.-W., Potenza, M. N., Xia, C.-C., Lan, J., Liu, L., Wang, L.-J., Liu, B., Ma, S.-S., & Fang, X.-Y. (2016). Effects of craving behavioral intervention on neural substrates of cue-induced craving in Internet gaming disorder. *NeuroImage. Clinical*, *12*, 591–599. https://doi.org/10.1016/j.nicl.2016.09.004

Zhang, Y., Lin, X., Zhou, H., Xu, J., Du, X., & Dong, G. (2016). Brain Activity toward Gaming-Related Cues in Internet Gaming Disorder during an Addiction Stroop Task. *Frontiers in Psychology*, *7*, 714. https://doi.org/10.3389/fpsyg.2016.00714

Zhou, W.-R., Wang, M., Dong, H.-H., Zhang, Z., Du, X., Potenza, M. N., & Dong, G.-H. (2021). Imbalanced sensitivities to primary and secondary rewards in internet gaming disorder. *Journal of Behavioral Addictions*, *10*(4), 990–1004. https://doi.org/10.1556/2006.2021.00072

Zhou, X., Zimmermann, K., Xin, F., Zhao, W., Derckx, R. T., Sassmannshausen, A., Scheele, D., Hurlemann, R., Weber, B., Kendrick, K. M., & Becker, B. (2019). Cue Reactivity in the Ventral Striatum Characterizes Heavy Cannabis Use, Whereas Reactivity in the Dorsal Striatum Mediates Dependent Use. *Biological Psychiatry. Cognitive Neuroscience and Neuroimaging*, *4*(8), 751–762. https://doi.org/10.1016/j.bpsc.2019.04.006

Zhou, Y., Xiang, H., Chen, J. Y., Li, X. Y., Wang, T., Li, W. C., Liu., Y. C., & Zhai., M. X., (2018). A functional magnetic resonance imaging study of the Stroop effect in adolescents with internet gaming disorder. *Chin J Psychiatry,* *51*(5), 329–334. https://doi.org/10.3760/cma.j.issn.1006-7884.2018.05.009

[周于, 向慧, 陈洁宇, 李心怡, 王涛, 李武超, 刘远成, & 翟茂雄. (2018). 网络游戏障碍青少年执行 Stroop 任务的脑功能磁共振成像研究. *中华精神科杂志,* *51*(5), 329–334. https://doi.org/10.3760/cma.j.issn.1006-7884.2018.05.009]

The neural activities of similarities and differences in substance and behavioral addictions: A meta-analysis based on task types

According to the dual-system theory of addiction, both substance and behavioral addictions are caused by the interaction between the reflective system represented by the prefrontal cortex and the impulsive system represented by the striatum. However, while most current studies examine the changes in the reflective and impulsive systems of substance and behavioral addictions separately, the overall understanding of these under different tasks remains incomplete. There is a need for further exploration of the commonalities and differences in the neural mechanisms between different types of addictions. Therefore, the current study used meta-analysis to investigate the neural activation patterns of substance and behavioral addictions in three types of tasks: inhibition control, reward processing, and craving induction. Then, contrast analysis was used to evaluate the similarities and differences in neural activation patterns of substance and behavioral addictions in these three tasks.

The current study used activation likelihood estimation (ALE) to conduct a meta-analysis of neuroimaging data. The substance addiction included 22 inhibition control tasks, 9 reward processing tasks, and 17 craving induction tasks. The behavioral addiction included 15 inhibition control tasks, 22 reward processing tasks, and 12 craving induction tasks. The meta-analysis was conducted in the standard Montreal Neurological Institute (MNI) space, and GingerALE (3.0.2) was used to convert the Talairach coordinates obtained in the studies to MNI coordinates. The probability maps used $p < 0.001$ (Uncorrected) as threshold. The minimum cluster size was set at 250 mm^3. Finally, under the three different tasks, contrast analysis was performed on substance and behavioral addictions. Group similarities and differences were examined using contrast analyses. The threshold for group-contrasts was set to $p < 0.01$ uncorrected for multiple comparisons with 10000 permutations, and the minimum cluster size was greater than 50mm^3.

The results found that: (1) In inhibition control tasks, substance addictions and behavioral addictions do not have the same activated brain areas; however, substance addictions exhibit decreased activation in the dorsolateral prefrontal cortex, while behavioral addictions show increased activation in the dorsolateral prefrontal cortex. (2) In cue-induced craving tasks, both substance addictions and behavioral addictions showed increased activation in the inferior frontal

gyrus. (3) In reward processing tasks, substance addictions exhibit stronger activation in the striatum than behavioral addictions.

In summary, the current meta-analysis shows that substance addictions and behavioral addictions exhibit differences and similarities in neural mechanisms in the prefrontal cortex and striatum in inhibition control, cue-induced craving, and reward processing tasks. In the striatum system, although substance addiction showed stronger activation increase than behavioral addiction in reward-related tasks, both substance and behavioral addictions showed abnormal activation increase. However, in the dorsolateral prefrontal cortex, behavioral addiction only showed a substance addiction-like response when induced by addictive cues; in inhibition control, the dorsolateral prefrontal cortex activation decreased in substance addiction, while it increased in behavioral addiction, allowing behavioral addiction to meet task requirements through compensatory activation.

Key words meta-analysis; substance addiction; behavioral addiction; reward processing; inhibitory control